PB80-159262

Combined Sewer Overflow Abatement Program, Rochester, NY. Volume II Pilot Plant Evaluations

O'Brien and Gere Engineers, Inc, Syracuse, NY

Prepared for

Municipal Environmental Research Lab
Cincinnati, OH

Jul 79

U.S. Department of Commerce
National Technical Information Service
NTIS

United States
Environmental Protection
Agency

Municipal Environmental Research
Laboratory
Cincinnati OH 45268

EPA-600/2-79-031b
July 1979

PB80-159262

Research and Development

Combined Sewer Overflow Abatement Program Rochester, NY

Volume II. Pilot Plant Evaluations

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, U.S. Environmental Protection Agency, have been grouped into nine series. These nine broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The nine series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies
6. Scientific and Technical Assessment Reports (STAR)
7. Interagency Energy-Environment Research and Development
8. "Special" Reports
9. Miscellaneous Reports

This report has been assigned to the ENVIRONMENTAL PROTECTION TECHNOLOGY series. This series describes research performed to develop and demonstrate instrumentation, equipment, and methodology to repair or prevent environmental degradation from point and non-point sources of pollution. This work provides the new or improved technology required for the control and treatment of pollution sources to meet environmental quality standards.

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-79-031b

2.

3. RECIPIENT'S ACCESSION NO. PB80-159262

4. TITLE AND SUBTITLE
Combined Sewer Overflow Abatement Program,
Rochester, NY - Volume II: Pilot Plant Evaluations

5. REPORT DATE July 1979 (Issuing Date)

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Frank J. Drehwing, Cornelius B. Murphy, Jr., Steven R. Garver, Donald F. Geisser, Dilip Bhargava

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
O'Brien & Gere Engineers, Inc.
1304 Buckley Road
Syracuse, New York 13221

10. PROGRAM ELEMENT NO. 1BC822, SOS 1, Task 31

11. GRANT NO. Y005141

12. SPONSORING AGENCY NAME AND ADDRESS
Municipal Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

13. TYPE OF REPORT AND PERIOD COVERED Final May 1974 to Sept. 1977

14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES Joint Sponsorship with: Great Lakes National Program Office, U.S. Environmental Protection Agency, Chicago, Illinois 60604. Project Officers: Richard Field & Anthony N. Tafuri, FTS 340-6674, (201) 321-6674

16. ABSTRACT - The pilot plant treatability studies were designed to interact with combined sewer overflow (CSO) monitoring and system modeling efforts for the Rochester Pure Water District with the ultimate objective of evaluating CSO abatement alternatives (see Volume I of this Report).

The studies covered treatment by the following unit processes: flocculation/sedimentation, swirl degritting and swirl primary separation, microscreening with sonic cleaning, dual-media filtration, activated carbon adsorption, sludge dewatering and high-rate disinfection. Applied flowrates to the system ranged between 5 and 177 gpm.

Pilot operations covered 19 overflow events during the period of September 1975 through June 1976. The studies evaluated the effects of design loadings and influent quality on system performance. Data were evaluated through application models. These models were used to develop optimum cost/benefit comparisons of systems. Results were also compared to published literature for similar installations at other locations.

Cost estimates related to facility sizing of all treatment processes were compiled and documented from literature sources. Cost equations were developed and applied for comparison of a number of alternatives in conjunction with the performance models. Cost/benefit relationships of the individual primary and chemical/physical systems are also presented in this report.

Reproduced from best available copy.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Combined sewers, *Overflows--sewers, Water pollution, *Waste treatment, Sewage, Contaminants, Sewage treatment, *Pilot Plants, Cost analysis, *Cost effectiveness, *Flocculating, *Sedimentation, *Swirling, Gravity concentrators, Grit removal, Strainers, *Filtration, *Activated carbon treatment, *Disinfection, Bactericides, *Mathematical models, Sludge, Mixing, Polyelectrolytes.	Physical-chemical treatment, *Combined sewer overflows, Pollution abatement, Water pollution control, Rochester, N.Y., Suspended solids removal, *Flocculation/sedimentation, *Swirl degritter, *Swirl primary separator, *Microscreening, *Wastewater treatment, *High-rate dual-media filtration, *Carbon adsorption, *High-rate disinfection, Chlorine dioxide, Alum, Mixing intensity, Storm runoff.	13B

18. DISTRIBUTION STATEMENT
RELEASE TO PUBLIC

19. SECURITY CLASS (This Report) UNCLASSIFIED

20. SECURITY CLASS (This page) UNCLASSIFIED

21. NO. OF PAGES 216

22. PRICE

EPA Form 2220-1 (9-73)

U.S. GOVERNMENT PRINTING OFFICE 1979 -657-060/5437

EPA-600/2-79-031b
July 1979

COMBINED SEWER OVERFLOW ABATEMENT PROGRAM, ROCHESTER, N.Y.

Volume II. Pilot Plant Evaluations

by

Frank J. Drehwing
Cornelius B. Murphy, Jr.
Steven R. Garver
Donald F. Geisser
Dilip Bhargava
O'Brien & Gere Engineers, Inc.
Syracuse, New York 13221

Grant No. Y005141

Project Officers
Richard Field/Anthony Tafuri
Storm and Combined Sewer Section
Wastewater Research Division
Municipal Environmental Research
Laboratory (Cincinnati)
Edison, New Jersey 08817

Lawrence Moriarty
Region II
Rochester, New York 10007

Grant Officer
Ralph G. Christensen
Great Lakes Demonstration Program
Great Lakes National Program Office
Region V, Chicago, Illinois 40604

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

and

GREAT LAKES NATIONAL PROGRAM OFFICE
U.S. ENVIRONMENTAL PROTECTION AGENCY
CHICAGO, ILLINOIS 60604

DISCLAIMER

This report has been reviewed by the Municipal Environmental Research Laboratory and the Great Lakes National Program Office, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

The Great Lakes National Program Office, through Section 108(a) of PL 92-500, enters into grants for the demonstration of new methods and techniques and for the development of preliminary plans for the prevention, reduction or elimination of pollution within all or any part of the watersheds of the Great Lakes. The Great Lakes National Program Office has joined with the Municipal Environmental Research Laboratory in carrying out this research and demonstration project to assist the Rochester Pure Waters District to eliminate an urban drainage pollution problem to Lake Ontario.

The deleterious effects of storm sewer discharges and combined sewer overflows upon the nation's waterways have become of increasing concern in recent times. Efforts to alleviate the problem depend upon characterization of these flows both as to quantity and quality. This report describes the results of pilot plant studies of a number of treatment technologies for controlling the quality of combined sewer overflow discharges.

Francis T. Mayo
Director
Municipal Environmental Research
Laboratory

Dr. Edith J. Tebo
Director
Great Lakes National
Program Office

ABSTRACT

The Rochester Pilot plant treatability studies were designed to interact with combined sewer overflow (CSO) monitoring and system modeling efforts for the Monroe County Pure Waters District with the ultimate objective of evaluating CSO abatement alternatives, as presented in Volume I of this Report.

The studies covered treatment by the following unit processes: flocculation/sedimentation (F/S), swirl degritter and swirl primary separator, microscreening with sonic cleaning, dual-media high-rate filtration, activated carbon adsorption, sludge dewatering and high-rate disinfection. Applied flowrates to the system ranged between 0.3 and 11.2 l/s (5 and 177 gpm).

Pilot operations covered nineteen overflow events during the period of September 1975 through June 1976. The studies evaluated the effects of design loadings and influent quality on system performance. Data were evaluated through application of statistical techniques and development of mathematical performance models. These models were used to develop optimum cost/benefit comparisons of systems. Results were also compared to published literature for similar installations at other locations.

The flocculation/sedimentation system was evaluated employing surface overflow rates from 33 to 82 m^3/day m^2 (800 to 2000 gpd/ft^2). Mathematical performance models were developed for the three chemical treatment cases. These models related SS removal rates to overflow rate and influent SS concentrations.

The swirl separators were pilot tested at flowrates ranging from 0.9 to 4.4 l/s (15 to 70 gpm). Mathematical performance models were developed for each system relating SS removal rates to influent flowrate and influent SS concentration. Chemical treatments were tested on the swirl primary system, but the in-line flocculation technique did not provide sufficient energy to permit effective floc development. The performance equations were compared to previously developed design curves for swirl concentrators.

Testing of the microscreen system was limited due to equipment malfunction. Headloss development across the screen was shown to be related to both hydraulic loading and screen rotational speed. The maximum hydraulic loading attainable for most of the dry and wet-weather testing was on the order of 550 l/min m^2 (13.5 gpm/ft^2) of screen surface when using a 70 micron screen.

Dual-media high-rate filters (DMHRF) were evaluated at hydraulic loading rates between 407 to 1018 l/min m^2 (10 to 25 gpm/ft^2). Results are compared for filtration with no chemical addition and with polyelectrolyte alone and alum plus polyelectrolyte. The performance curves show the effects of the chemical addition and the impact of the upstream (swirl primary separator) treatment on performance of the DMHRF.

Operation of the carbon adsorption system was limited to three storms. Detention times of 13.5 to 45 minutes were evaluated. Optimum BOD_5 removals (80-95 percent) were attained at detention times of 20 to 30 minutes.

Multiple regression modeling of the chlorine (Cl_2) and chlorine dioxide (ClO_2) disinfection data yielded statistically significant equations for the high-rate disinfection systems. The models indicated that disinfection by Cl_2 is more sensitive to mixing intensity and detention time than disinfection by ClO_2. System cost optimization procedures indicated that ClO_2 permitted use of lower detention time facilities. The use of Cl_2 permitted lower overall cost systems relative to ClO_2 for all trial cases of required kill and wastewater quality.

A review of literature is presented on solids handling considerations involved with treatment of CSO.

Cost/benefit comparisons of the F/S and swirl primary separator systems are presented. Cost/benefits of chemical treatment programs are also presented. Cost/benefits of regional configuration alternatives (central versus local treatment) and storage versus treatment sizing are presented in Volume I of this Report.

This report was submitted in fulfillment of Grant No. Y005141 by O'Brien & Gere Engineers, Inc. under the partial sponsorship of the U.S. Environmental Protection Agency. This report covers the period from May 4, 1974 to November 1976, and work was completed as of September 1977.

CONTENTS

Foreword.......... iii
Abstract.......... iv
Figures.......... ix
Tables.......... xiii
Abbreviations and Symbols.......... xv
Acknowledgment.......... xvii

1. Introduction.......... 1
2. Conclusions.......... 4
3. Recommendations.......... 7
4. Pilot Plant Facilities.......... 9
    General.......... 9
    Pumping Station.......... 10
    Flocculation/Sedimentation System.......... 14
    Swirl Concentrators.......... 15
    Microscreening System.......... 18
    Storage Tanks.......... 18
    Dual Media Filters.......... 18
    Carbon Adsorption.......... 20
    Disinfection System.......... 22
5. Project Plan.......... 24
    Program Development and Application of Results.......... 24
    Scope of Work.......... 24
6. Flocculation/Sedimentation.......... 27
    Background.......... 27
    Outline of Experiments.......... 28
    Chemical Treatment Requirements.......... 30
    Suspended Solids Removal.......... 31
    Scaleup Considerations.......... 35
    Removal of Other Constituents.......... 37
7. Swirl Concentrators.......... 43
    Background.......... 43
    Outline of Experiments.......... 46
    Swirl Degritter.......... 50
    Swirl Primary Separator.......... 56
    Removal of Other Constituents.......... 60
8. Microscreening.......... 68
    General.......... 68
    Outline of Experiments.......... 69
    Results and Performance.......... 69
9. Dual-Media,High-Rate Filtration.......... 75
    Background.......... 75
    Outline of Experiments.......... 76
    Operating Procedures.......... 79

CONTENTS (continued)

Results 80

10. Activated Carbon Adsorption 91
    Background 91
    Outline of Experiments 91
    Results 92

11. High-Rate Disinfection 95
    Background 95
    Test Program 96
    Single Stage Treatment: Chlorine vs. Chlorine Dioxide ... 98
    Chlorine/Chlorine Dioxide Combinations 109

12. Solids Handling Considerations 122
    Sludge Thickening 122
    Sludge Dewaterability 123
    Discussion 123

13. Capital and Operating Cost Estimates 136
    Basis of Cost Estimates 136
    Capital Costs 136

14. Comparison of Alternatives 141
    Cost/Benefit Comparison of Swirl Primary Separator versus Flocculation/Sedimentation 141
    Secondary Level Treatment Alternatives 142
    Miscellaneous Costs 143
    Discussion 143

References 146

Appendices

Reproduced from best available copy.

A. SS vs time plots-flocculation/sedimentation and swirl concentrators 152

B. Statistical analysis of influent and effluent data-flocculation/sedimentation and swirl concentrators 162

C. Statistical analysis of influent and effluent data-microscreen system 179

D. Statistical analysis of effluent data-DMHRF system 182

E. Cl_2 and ClO_2 analytical data 190

FIGURES

Number Page

1 Pilot Plant and Pumping Station Locations........................ 9

2 Rochester Pilot Plant Facilities................................. 11

3 Rochester Pilot Plant Facilities................................. 12

4 Flocculation/Sedimentation Tank (Pilot Unit)..................... 15

5 Swirl Degritter (Pilot Unit)..................................... 16

6 Swirl Primary Separator (Pilot Unit)............................. 17

7 The FMC Sonic Cleaner Microscreen (Pilot Unit)................... 19

8 Storage Tank... 20

9 Dual-Media High-Rate Filter (Pilot Unit)......................... 21

10 Activated Carbon Column (Pilot Unit)............................ 21

11 Pilot Disinfection Tank and Mixing Concepts..................... 22

12 Comparison of Polyelectrolyte Types............................. 30

13 Selection of Polyelectrolyte Dosage............................. 31

14 Variation in Alum Demand.. 32

15 Performance of Flocculation/Sedimentation System @ 800 gpd/ft^2... 35

16 Performance of Flocculation/Sedimentation System @ 1500 gpd/ft^2.. 36

17 Performance of Flocculation/Sedimentation System @ 2000 gpd/ft^2.. 36

18 Loading-Performance Relationships: Flocculation/Sedimentation System.. 37

19 Swirl Regulator/Concentrator.................................... 44

20 Swirl Degritter... 44

21 Swirl Primary Separator... 44

FIGURES (continued)

Number Page

22 Combined Sewer Overflows: Particle Size Distribution............. 49

23 Swirl Degritter: Model and Prototype Particle Size Distributions. 51

24 Performance of Swirl Degritter (6 ft dia. unit).................. 55

25 Swirl Primary Separator: Regression Model and Performance Data... 58

26 Swirl Primary Separator: Loading-Performance Relationship........ 58

27 Swirl Primary Separator: Model and Prototype Particle Size Distributions.. 60

28 Microscreen System Performance.................................. 70

29 Microscreen System Performance.................................. 70

30 Microscreen System Performance.................................. 72

31 Microscreen System Performance.................................. 72

32 Microscreen System Performance.................................. 73

33 Microscreen System Performance.................................. 73

34 Typical Filter (DMHRF) Performance Curves....................... 81

35 DMHRF Run Lengths.. 82

36 DMHRF Run Lengths.. 82

37 DMHRF Run Lengths.. 83

38 DMHRF Specific Capture... 84

39 DMHRF Specific Capture... 84

40 DMHRF Performance.. 86

41 DMHRF Performance.. 87

42 BOD_5 Removal With Carbon Adsorption........................... 93

43 BOD_5 Removal With Carbon Adsorption........................... 93

44 BOD_5 Removal With Carbon Adsorption........................... 94

45 Comparison of Regression Model With Literature Results..........103

FIGURES (continued)

Number Page

46 Effect of Cl_2 Dose in Regression Models....104

47 Effect of ClO_2 Dose in Regression Models....105

48 Effect of BOD_5 in Regression Models....105

49 Effect of TKN in Regression Models....106

50 Predicted vs. Observed Bacterial Reductions for Chlorine....107

51 Predicted vs. Observed Bacterial Reductions for Chlorine Dioxide....108

52 Optimization Trends....110

53 Two Stage Disinfection Iso-kill Curves....113

54 Two Stage Disinfection Iso-kill Curves....113

55 Two Stage Disinfection Iso-kill Curves....114

56 Two Stage Disinfection Iso-kill Curves....114

57 Two Stage Disinfection Iso-kill Curves....116

58 Two Stage Disinfection Iso-kill Curves....116

59 Comparison of Order of Addition: Cl_2-ClO_2 Combinations....117

60 Comparison of Order of Addition: Cl_2-ClO_2 Combinations....118

61 Comparison of Order of Addition: Cl_2-ClO_2 Combinations....119

62 Comparison of Order of Addition: Cl_2-ClO_2 Combinations....120

63 Comparison of Order of Addition: Cl_2-ClO_2 Combinations....121

64 CSO Primary Treatment Sludge Settling Curves....122

65 Sludge Dewaterability Tests....124

66 Sludge Dewaterability Tests....124

67 Sludge Dewaterability Tests....125

68 Sludge Dewaterability Tests....125

69 Sludge Aging Studies....126

FIGURES (continued)

Number Page

70 Sludge Aging Studies....................126

71 Sludge Aging Studies....................127

72 Cost-Performance Comparisons....................144

73 Cost-Performance Comparisons....................144

TABLES

Number Page

1 Pilot Plant Design Parameters.................................. 13

2 Storm Characteristics.. 26

3 Flocculation/Sedimentation System Test Matrix.................. 29

4 Multiple Regression Analysis of Flocculation/Sedimentation Data: No Chemical Treatment.. 33

5 Multiple Regression Analysis of Flocculation/Sedimentation Data: Treatment with Anionic Polymer................................ 34

6 Multiple Regression Analysis of Flocculation/Sedimentation Data: Treatment with Alum and Anionic Polymer...................... 34

7 Flocculation/Sedimentation System-Median Removals............... 39

8 Percent VSS of SS - Flocculation/Sedimentation System............ 42

9 Swirl Degritter and Primary Separator Test Matrix............... 46

10 Swirl Degritter and Primary Separator: Model and Prototype Flow Rates.. 47

11 Particle Settling Distributions................................ 48

12 Grit Solids Distribution...................................... 51

13 Swirl Degritter-Model to Prototype Scaling of Particle Sizes..... 53

14 Regression Analysis of Pilot Plant Swirl Degritter Data.......... 54

15 Regression Analysis of Pilot Plant Swirl Primary Separator Data.. 57

16 Swirl Primary Separator-Model to Prototype Scaling of Particle Sizes.. 59

17 Swirl Degritter System-Median Removals......................... 61

18 Swirl Primary Separator System-Median Removals.................. 64

19 Swirl Degritter - Percent VSS of SS............................ 67

TABLES (continued)

Number Page

20 Swirl Primary Separator - Percent VSS of SS...................... 67

21 Microscreening Analytical Data.................................. 74

22 DMHRF Operating Conditions...................................... 77

23 Sieve Analysis of Filter Media.................................. 79

24 Median Performance of DMHRF..................................... 88

25 Activated Carbon Operating Conditions........................... 91

26 Summary of Wet-Weather Disinfection Operating Conditions......... 97

27 Summary of Dry-Weather Disinfection Operating Conditions......... 98

28 Multiple Regression Analysis Results for Disinfection by Cl_2.....101

29 Multiple Regression Analysis Results for Disinfection by ClO_2....101

30 Cost Optimization. CSO-Primary Effluent........................111

31 Cost Optimization. CSO-Filtered Effluent.......................111

32 Cost Optimization. CSO-Activated Carbon Effluent...............111

33 Estimated Loadings for 100 Percent CSO Treatment................123

34 Rochester Pilot Plant Volatile Solids Fractions.................129

35 Pilot Plant CSO Heavy Metals Data...............................129

36 Heavy Metal Characteristics of CSO Sludges......................130

37 Sludge Processing Facilities....................................134

LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

ALPPH -- alum feed rate
APWA -- American Public Works Association
ASCE -- American Society of Civil Engineers
BOD_5 -- 5 day biochemical oxygen demand at 20C
cal -- calories
cc -- chemical cost
c_e -- effluent suspended solids concentration
cm -- centimeters
c_o -- influent suspended solids concentration
COD -- chemical oxygen demand
CSO -- combined sewer overflow
D.T. -- detention time
D_2/D_1 -- chamber diameter/inlet diameter
dia -- diameter
DMHRF -- dual-media high-rate filter
DOSE -- chemical dosage
e.s. -- effective size
FBV -- flocculation basin volume
ft -- feet
ft^2 -- square feet
ft^3 -- cubic feet
fpm -- feet per minute
F/S -- flocculation/sedimentation
G -- velocity gradient (sec^{-1}or min^{-1}, as specified)
GT -- effective mixing intensity
gal -- gallons
g -- grams
g_c -- effluent grit concentration
g_o -- Influent grit concentration
gpd -- gallons per day
gpm -- gallons per minute
G/S -- swirl degritter
hr -- hour
ha -- hactares
H_1/D_2 -- weir height/swirl chamber diameter
hp -- horsepower
in -- inches
kg -- kilograms
l -- liters
LC -- labor cost
l/s -- liters/second
m -- meters

ABBREVIATIONS (continued)

m^2 -- square meters
m^3 -- cubic meters
mg -- miligrams
mil gal -- million gallons
mqd -- million gallons per day
MGTPY -- million gallons treated per year
ml -- milliliter
mm -- millimeter
min -- minute
mg/l -- milligrams/liter
M/S -- microscreen
N -- Newtons
NOF -- number of overflow events per year
NUMUNITS -- number of swirl units
N_F -- Froude number
O&G -- oil and grease
OR -- overflow rate
PC -- power cost
PCB -- polychlorinated biphenyl
POLPPH -- polymer feed rate
P/S -- swirl primary separator
PVC -- polyvinyl chloride
R-M -- rapid mix
rpm -- revolutions per minute
SA -- surface area
S.G. -- specific gravity
SETTS -- settleable solids
scfm -- standard cubic feet per minute
SS -- suspended solids
SWMM -- stormwater management model
T -- contact time
TIP -- total inorganic phosphorus
TKN -- total Kjeldahl nitrogen
TOC -- total organic carbon
TS -- total solids
USEPA -- United States Environmental Protection Agency
v -- velocity
V -- basin volume
VSS -- volatile suspended solids
WOR -- weir overflow rate

SYMBOLS

Al -- aluminum
Cl_2 -- chlorine
ClO_2 -- chlorine dioxide
P -- phosphorus
Q -- flowrate, units as specified
/ -- per (to indicate rates)
$ mil -- million dollars

ACKNOWLEDGMENTS

O'Brien & Gere Engineers, Inc., gratefully acknowledges the cooperation of the Monroe County Division of Pure Waters. Appreciation is expressed to Dr. Gerald McDonald, Director, Thomas Quinn, Chief of Technical Operations, Robert Hallenbeck, former Chief of Technical Operations, and James Stewart of the Monroe County Division of Pure Waters for their cooperation and assistance.

The support of this effort by the Storm and Combined Sewer Section, Eidson, New Jersey of the USEPA Municipal Environmental Research Laboratory, Cincinnati, Ohio and of the Office of the Great Lakes Coordinator, Region V, USEPA, Chicago, Illinois and especially of Richard Field, Chief, Anthony Tafuri, Project Officer, Storm and Combined Sewer Section, Ralph Christensen, Chief, Section 108a Great Lakes Demonstration Program, and Larry Moriarty, Project Officer, USEPA, Region II for their guidance, suggestions and contributions is acknowledged with gratitude.

This report has been prepared by O'Brien & Gere Engineers, Inc., Syracuse, New York under the direction of Frank J. Drehwing, Vice President, and Cornelius B. Murphy, Managing Engineer.

SECTION 1

INTRODUCTION

BACKGROUND

The significance of pollution caused by storm-generated discharges has been well documented. A large portion of this pollution is associated with overflows or relief points in combined sewer systems. A nationwide survey by the APWA (1) indicated that combined sewers are used in more than 1300 municipalities serving a population of 54 million. The magnitude of the overflow problem was exemplified by a 2-year study conducted on a 92.7 ha (229 acre) combined sewer watershed in Northampton, England. This study showed that the cumulative yearly five-day biochemical oxygen demand (BOD_5) load in the combined sewer overflows nearly equaled the BOD_5 load contained in the effluent of the local secondary treatment plant. Suspended solids within the overflows were three times the load contributed by the treatment work effluent (1).

Another aspect of the problem was illustrated in a report on the combined sewers in Buffalo, N.Y. (2). In Buffalo, 20 to 30 percent of the annual collection of domestic sewage solids settle in the sewers during dry periods and are eventually discharged during storms. This results in shock loadings which are detrimental to aquatic life in the receiving water.

The most obvious solution to abatement of combined sewer overflows (CSO) is construction of separate storm sewer networks. In terms of dollars per acre served, this is a very costly alternative and is technically difficult in heavily populated and developed urban areas. Moreover, it is possible that quality control of storm sewer discharges may be necessary in the future.

CSO abatement alternatives have been classified into three groupings: (a) nonstructural alternatives, (b) minimal-structural alternatives and (c) capital intensive alternatives. These have been described in detail in Volume I of this Report (3).

Many CSO abatement techniques such as regulator adjustments, elimination of interceptor constraints and in-system storage, while reducing overflow volumes, result in containment of large volumes of wastewater which require treatment. Ideally, the flow-attenuating techniques would allow treatment of the additional contained wastewaters in existing dry-weather treatment facilities during nonstorm periods. However, it appears that existing dry-weather treatment facilities in many communities do not have either the hydraulic or solids-handling capabilities to adequately treat even attenuated storm flows. These stormwater contributions could cause very serious hydraulic and toxic upset conditions in biological treatment systems not specifically designed for this impact.

Therefore, an integral part of most CSO abatement programs is consideration of the treatment technologies to be applied to the intercepted wet-weather flows. Since the characteristics of combined sewage are quite different from those of dry-weather domestic sewage, different treatment concepts may be applied to wet-weather flows. For example, wet-weather suspended solids generally exhibit a fairly coarse size distribution and may readily be removed in primary facilities operated at relatively high hydraulic loading rates.

PURPOSE OF STUDY

The pilot plant treatability studies were undertaken to delineate the treatment alternatives available for control of CSO quality in the Rochester Pure Waters District of Monroe County, New York.

The direction of the pilot plant study was based partly on requirements outlined by the USEPA (73). These requirements stated that all CSO shall have a minimum of primary treatment, phosphate removal,and chlorination with absolutely no bypassing.

A major emphasis of the study was the development of cost/benefit comparisons of processes that would allow primary-level treatment efficiencies. These processes were compared relative to their response to treating variable-quality influent wastewater. Treatment of the highly concentrated first-flush overflow was of particular importance. Most of the comparisons centered around the flocculation/sedimentation and swirl separator systems. Evaluations of chemical treatments were instrumental for the determination of optimum conditions.

Previous studies of the District's combined system (74, 75) cited deficiencies of the existing sewerage system and the effects of wastewater discharges on the area receiving waters. Those studies recognized that measures were necessary for collection, transmission, control and treatment of combined wastewaters originating within the City of Rochester. Subsequent studies (76) have reinforced the earlier studies and documented the impact of CSO on the Genesee River and the Rochester Embayment of Lake Ontario. The objective of this study was to outline a plan of best management practices through a program of CSO monitoring, system modeling and treatability studies. The treatability studies reported herein were designed specifically to interact with the modeling efforts and evaluations of abatement alternatives. The treatability studies and cost estimates were particularly instrumental to evaluation of satellite overflow treatment versus centralized treatment and determination of storage versus treatment capacity optimizations.

The treatment processes included in this study represent those systems that are currently receiving prime nationwide consideration for treatment of CSO. Combinations of the piloted processes could result in process trains capable of providing treatment efficiencies from grit removal through tertiary treatment quality and disinfection. A secondary objective of the pilot program was to provide additional expansion of the nationwide data base for evaluating CSO treatability. Every effort was made to compare results of this study to results reported for similar installations at other locations.

SECTION 2

CONCLUSIONS

1. Most CSO abatement techniques result in containment of large volumes of wastewater which require treatment.

2. High-rate physical and/or chemical treatment processes are well suited to the abatement of pollution from CSO.

3. Multiple regression modelling of the F/S data indicated the following general relationships:

Influent SS (mg/l)	% Removal of SS OR (gpd/sq ft) 800	 1500	 2000
No Chemical Treatment			
200	15.9	12.0	10.1
500	60.9	59.1	58.2
With Polymer Treatment			
200	53.1	47.6	44.9
500	77.6	75.0	73.7
With Alum plus Polymer			
200	78.2	75.4	74.0
500	89.3	87.9	87.2

Performance of the flocculation/sedimentation (F/S) pilot system was significantly enhanced by incorporation of chemical treatment. Percentage removal of suspended solids (SS) in the F/S system was highly dependent on influent SS concentration as well as overflow rate (OR). Increasing OR from 33 to 82 $m^3/day\ m^2$ (800 to 2000 gpd/ft^2) in the F/S system resulted in only marginal loss of performance.

4. Performance of the pilot swirl degritter generally supported the data presented for the pilot swirl degritter evaluated at Denver.

Multiple regression analysis of the data from the 0.91-m (3-ft) dia swirl degritter developed the following general trends

Influent SS (mg/l)	% Grit Removal Flowrate (gpm) 15	 40	 70
100	69.0	59.8	54.6
300	100.0	91.0	85.7
400	100.0	99.1	93.8

5. After scaling of hydraulic flows and particle settling velocities to prototype scale, the performance data obtained from the pilot swirl primary separator unit generally supported the previously developed design curves developed by APWA.

   Multiple regression analysis of data from the 1.8-m (6-ft) dia swirl primary separator indicated the following:

	% SS Removal		
	Flowrate (gpm)		
Influent SS (mg/l)	15	40	70
100	56.5	32.5	13.3
300	66.6	48.1	33.3
500	70.4	54.1	41.0

6. The hydraulic loading to the FMC pilot microscreening system with ultrasonic cleaning appeared to be limited to about 550 l/min m^2 (13.5 gpm/ft^2) when using 70 micron screens. However, the data suggested that higher loadings might be attainable if screen rotation was increased above 136 rpm. SS removals averaged within the range of 1.5-43.5 percent when treating CSO.

7. Increasing hydraulic loading to the pilot dual-media high-rate filters (DMHRF) above 407 l/min m^2 (10 gpm/ft^2) tended to improve specific captures by dispersion of trapped solids deeper into the bed. However, without chemical treatment, SS removals fell rapidly at the higher loadings. When chemicals were employed on or upstream of the filters, performance loss at the higher influx was not as great.

	Flux (gpd/sq ft)	Average % SS Removal		Spec. Capture (lbs/sq ft)
		Range	Mean	
No chemical Treatment	10-15	56-83	67	1.34
	20-25	40-71	50	1.57
With chemical Treatment	10-15	66-92	78	1.31
	20-25	45-95	64	1.59

8. The application of carbon adsorption indicated optimum BOD$_5$ removal at detention times of 20 to 30 minutes.

Influent BOD$_5$ (mg/l)	Detention Time (min)	Flux (gpm/sq ft)	BOD$_5$ Removal (%)
30	13.5	0.42	69
30	19.3	0.61	76
30	30.0	0.94	83
30	45.0	1.41	79
70	13.5	0.42	92
70	19.3	0.61	91
70	30.0	0.94	96
70	45.0	1.41	88

9. Multiple regression modeling of Cl_2 and ClO_2 disinfection data yielded statistically significant performance equations for high-rate disinfection.

10. High-rate disinfection employing relatively short detention time and high-intensity mixing appeared to be a more cost effective method than conventional disinfection for the treatment of CSO. These procedures tend to increase operating costs while decreasing capital costs. CSO treatment facilities remain idle for much of the year; thus, operating cost is a smaller fraction of the overall cost for wet-weather facilities than for dry-weather plant.

11. Disinfection by Cl_2 was preferred to disinfection by ClO_2 on a cost performance basis when treating CSO with site factors specific to Rochester, NY.

12. Cost/benefit comparisons of the F/S and swirl primary separator systems indicated that the choice of treatment methodology for CSO was dependent on the influent quality and the degree of treatment required. In general, the swirl separator was cost competitive with F/S. However, chemical treatments incorporated into a F/S system permitted significantly enhanced removal efficiencies with fairly minor increases in operating costs.

13. Review of the literature indicates that, in general, sludges from CSO treatment should not be bled back to dry-weather treatment plants. Physical/chemical sludges at local overflow sites should be treated at separate on-site facilities. After considering site-specific factors at Rochester, the recommended sludge treatment included lime stabilization, thickening, vacuum filtration and land disposal.

SECTION 3

RECOMMENDATIONS

1. Future studies of flocculation/sedimentation of CSO should include evaluations of OR's above 82 m^3/day m^2 (2000 gpd/ft^2), especially when alum and polyelectrolyte are employed.
2. Pilot and prototype scale swirl units should be tested side-by-side to verify and establish the scaleup procedures for the pilot scale units.
3. Prototype verification testing should be conducted for the swirl degritter and swirl primary separator units.
4. Chemical treatment should be further evaluated in the swirl primary separator unit to study the enhancement in performance.
5. Because of operating difficulties encountered with the FMC Microscreen system, limited data were collected. CSO treatment data from other microscreen systems are available from references cited in the text. Future testing should evaluate loadings above 550 l/min m^2 (13.5 gpm/ft^2) and other screen mesh sizes.
6. This study suggested that treatment efficiency of units upstream of DMHRF had an impact on performance of the DMHRF. This impact should be evaluated further along with additional studies with chemical treatment.
7. It has been demonstrated that carbon adsorption provides significant removals of dissolved organics from CSO. Because of the high costs associated with carbon adsorption, its application should be limited to locations where receiving water loadings of dissolved organics and toxicants are critical.
8. The need for dechlorination of disinfected effluents resulting from high-rate disinfection systems using high Cl_2 dosages should be evaluated.
9. The formation of chlorinated organics and other refractory residuals in high-rate disinfection systems using high Cl_2 and ClO_2 dosages should be evaluated.
10. It is recommended that sludges resulting from the treatment of CSO generated from the Rochester system employ lime stabilization,

thickening, vacuum filtration, and either incineration or land disposal.

11. A more cost effective process should be developed for on-site generation of ClO_2.

12. The utility of employing the swirl separator concept for sludge concentration should be evaluated.

13. Additional process evaluations should be conducted to study the removal of toxicants known to be constituents of CSO.

SECTION 4

PILOT PLANT FACILITIES

GENERAL

The pilot plant facilities were installed at the Joseph-Ward Chlorination Station (Figure 1), a facility which had been abandoned as a chlorination station. It is located near the Central Avenue overflow site (designated as overflow No. 25 for the Characterization and Monitoring Program). The drainage area associated with this overflow comprises an area of 171.3 ha (423 acres), 137 ha (340 acres) of which could be characterized as commercial usage. The remainder of the area is associated mainly with residential use.

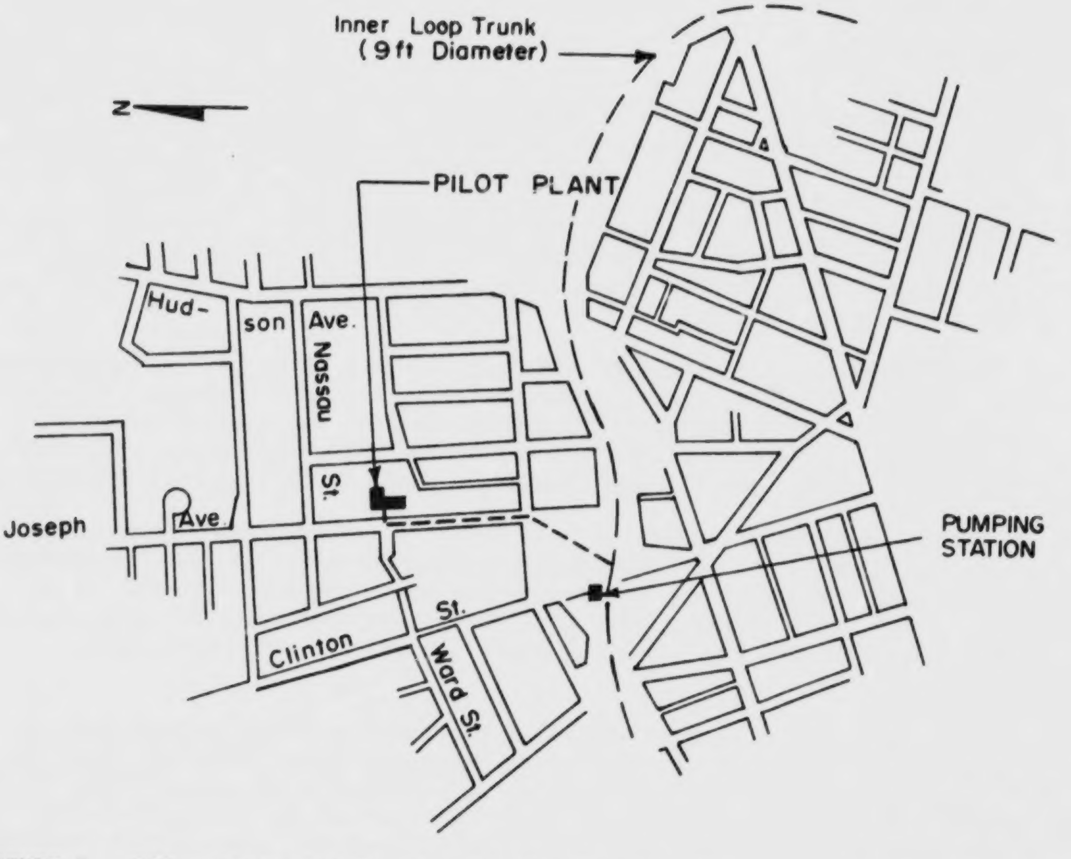

Inner Loop Trunk
(9ft Diameter)
N
PILOT PLANT
Hud-
son
Ave.
Nassau
St.
Joseph
Ave
Clinton
St.
Ward St.
PUMPING
STATION

FIGURE 1. Pilot Plant and Pumping Station Locations

Three types of treatment processes were investigated at the Rochester pilot plant: (1) primary solids separation; (2) chemical precipitation to achieve a greater degree of fine solids removal along with phosphorus reduction below the 1 mg/l level; and (3) final polishing and high-rate disinfection to achieve a secondary quality effluent with respect to BOD_5 and bacterial contamination. The primary solids removal processes tested and evaluated included high-rate sedimentation, microscreening, high-rate filtration, and swirl concentrators. The phosphorus removal processes tested and evaluated included chemical addition and flocculation prior to the high-rate sedimentation process and chemical addition prior to application on high-rate, dual-media filter beds. Polishing and high-rate disinfection included carbon filters to study the effect of providing the equivalent of secondary treatment to wet-weather discharges. The disinfection process was directed towards applying conclusions of earlier studies of chlorine and chlorine dioxide (42) and testing several mixing concepts to evaluate methods for achieving bacterial reductions within very short detention periods (five minutes or less).

Physical dimensions and design parameters of the pilot plant facilities are listed in Table 1. Figures 2 and 3 show photographs of the pilot plant facilities.

PUMPING STATION

The pumping station which provided the influent to the pilot plant was located upstream of the Central Avenue overflow in a section of the 3.66 m (12 ft) tunnel. The pumping station location, although not at the actual overflow site, collected runoff as part of the combined sewage from more than 95 percent of the drainage area. Pumping of flow to the pilot plant was accomplished through the use of two 10.2 cm (4 in) submersible high-head pumps. Each pump was capable of delivering 25.2 l/s (400 gpm) under a total head of 26 m (85 ft).

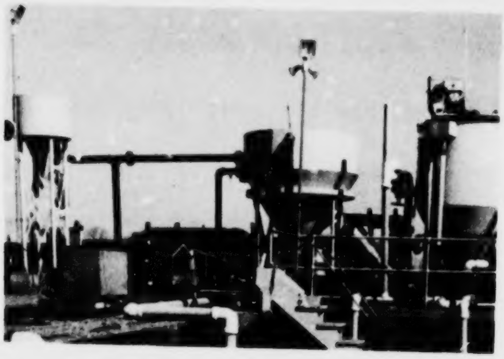
Immediately downstream of the pumps a 0.6 m (2 ft) weir was constructed in order to maintain a minimum level of flow around the pumps. This made it possible to operate the pumps under both dry and wet-weather conditions. A removable gate was installed in the weir which permitted the areas behind the weir and around the pumps to be cleaned periodically.

The pumps were controlled from the pilot plant by two alternative modes of operation. The pumps could be started manually and independent of flow conditions in the tunnel, or the pumps could be started inside the tunnel. An ultrasonic head probe and continuous recorder were used to monitor and record the amount of overflow produced with each storm occurrence.

Conveyance of flow to the pilot plant was provided through the use of a 15 cm (6 in) diameter pipe, approximately 457 m (1500 ft) long. A bypass valve controlled the flow of CSO into the pilot plant. Gate valves were used to control the flow into each of the treatment units. Flow measurements were made with magnetic flowmeters with direct reading indicators installed in the vicinity of the gate valves to monitor incoming flows.

Swirl Primary Separator (foreground) and Swirl Degritter (background)

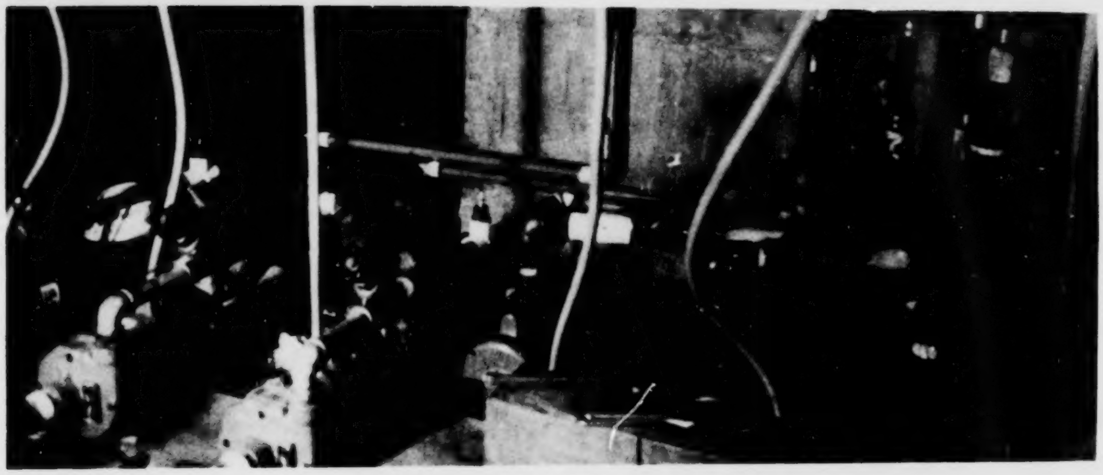
Cl_2 and ClO_2 High Rate Disinfection Tanks



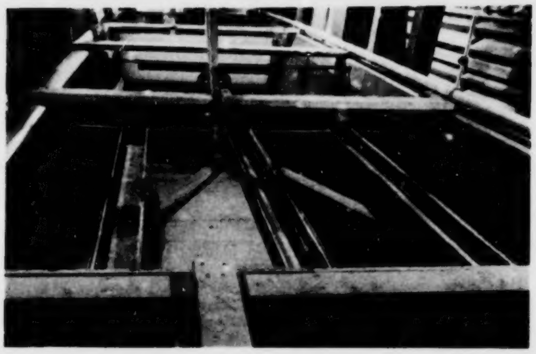
From left: Swirl Degritter, Swirl Primary Separator and Microscreen Unit

Storage Tanks (on ground)

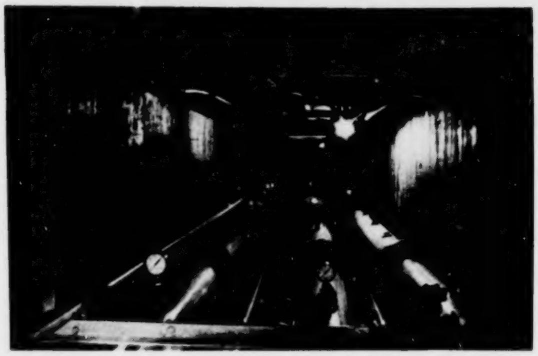
FIGURE 2. Rochester Pilot Plant Facilities



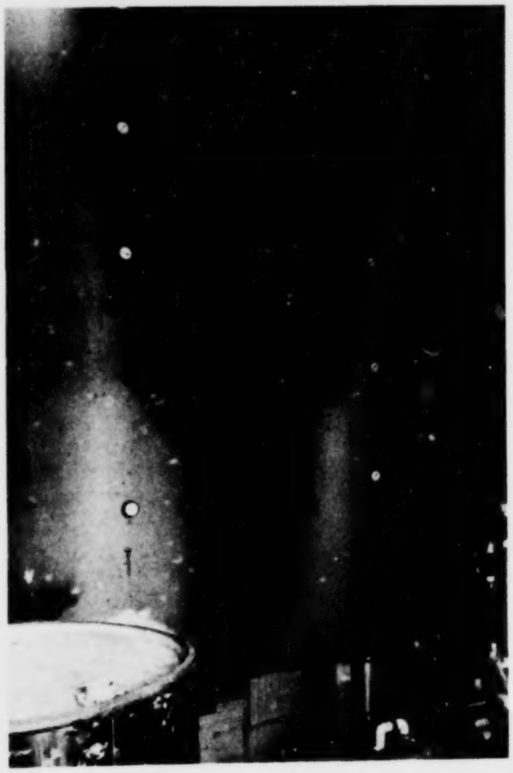
Influent and Effluent Pumps Associated with Dual Media Filter Columns



Flocculation--Sedimentation Basin



Dual Media Filter Columns for High Rate Filtration



Activated Carbon Columns

FIGURE 3. Rochester Pilot Plant Facilities

TABLE 1. PILOT PLANT DESIGN PARAMETERS

A.	Flocculation Basin	
1.	dimensions	2.1 m x 0.9 m x 1.98 m deep (7 ft x 3 ft x 6.5 ft)
2.	surface area	1.95 m^2 (21.0 ft^2)
3.	volume	3864 l (1021 gal)
4.	flow rates	4.5-11.2 l/s (71-177 gpm)
5.	detention times	5.1-10.1 min
6.	velocity gradient	120/sec
7.	mixing intensity (GT)	42000-104000
B.	Sedimentation Basin	
1.	dimensions	6.1 m x 2.1 m x 1.98 m deep (20 ft x 7 ft x 6.5 ft)
2.	surface area	11.8 m^2 (127.3 ft^2)
3.	volume	21900 l (5790 gal)
4.	flow rates	4.5-11.2 l/s (71-177 gpm)
5.	overflow rates	32.6-81.6 m^3/day m^2 (800-2000 gpd/ft^2)
6.	detention times	33-81 min
C.	Microscreen	
1.	dimensions	1.5 m dia. x 2.3 m (5 ft dia. x 7.5 ft)
2.	tank volume	3452 l (912 gal)
3.	screen surface area	0.56 m^2 (6.0 ft^2)
4.	flux	610-1221 l/min m^2 (15-30 gpm/ft^2) at full screen submergence
5.	flow rates	6-11 l/s (90-180 gpm)
6.	detention time	5.1 - 10.1 min
7.	maximum rotation	136 rpm
8.	screen aperture	10 or 70 microns
D.	Swirl Degritter	
1.	dimensions (overall)	0.9 m dia. x 1.2 m (3 ft dia. x 4 ft)
2.	D_2/D_1 ratio	6.0
3.	H_1/D_2 ratio	0.40
4.	chamber volume	214 l (56.5 gal)
5.	grit cone volume	61 l (16.0 gal)
6.	surface area	0.64 m^2 (6.87 ft^2)
7.	tested flow range	0.95-4.4 l/s (15 - 70 gpm)
8.	operating N_F	0.0018 - 0.0392
9.	detention time	1.04 - 4.83 min
E.	Swirl Primary Separator	
1.	dimensions (overall)	1.8 m dia x 1.8 m (6 ft dia. x 6 ft)
2.	D_2/D_1 ratio	18.0
3.	H_1/D_2 ratio	0.27
4.	chamber volume	1173 l (310 gal)
5.	sludge cone volume	1181 l (312 gal)

(continued)

TABLE 1. (continued)

6.	surface area	2.6 m^2 (28 ft^2)
7.	tested flow range	0.95 - 4.4 l/s (15 - 70 gpm)
8.	operating N_F	0.0137 - 0.298
9.	detention time	8.9 - 4.5 min
10.	equivalent OR	31.6 - 146.2 m^3/day m^2 (771-3600 gpd/ft^2)
F.	Dual-Media High-Rate Filters	
1.	dimensions	15 mm dia. x 5.5 m (0.5 ft x 18 ft)
2.	surface area	0.02 m^2 (0.196 ft^2)
3.	design flux	407 - 1018 l/min m^2 (10-25 gpm/ft^2)
4.	flow rates	7.6-18.9 l/min (2-5 gpm)
5.	media	1.5 m (5 ft) of No. 2 anthracite 0.9 m (3 ft) of No. 1220 sand
G.	Carbon Columns	
1.	dimensions	0.9 m dia. x 2.9 m (3 ft x 9.5 ft)
2.	surface area	0.66 m^2 (7.07 ft^2)
3.	operating flow range	0.19 - 0.63 l/s (3 - 10 gpm)
4.	detention time	13.5 - 45 min
5.	flux	17.3 - 57.3 l/min m^2 (0.42-141 gpm/ft^2)
6.	media	2.1 m (6.8 ft) of Filtrasorb 400
H.	Disinfection Tanks	
1.	dimensions	0.61 m x 0.61 m (2 ft x 2 ft)
2.	operating depths	15-37 mm (0.5 - 1.2 ft)
3.	volume	57 - 136 l (15 - 36 gal)
4.	operating flow rates	0.13 - 0.63 l/s (2 - 10 gpm)
5.	detention time	3.4 - 8.4 min
6.	mixing intensities (GT)	41400 - 179000

FLOCCULATION/SEDIMENTATION SYSTEM

The dimensions of the pilot flocculation/sedimentation system, shown in Figure 4, are listed in Table 1. The elevation of the overflow weir was adjustable so that both overflow rate and flow-through velocity could be varied. Overflow from the flocculation basin was directed by a baffle to the bottom of the sedimentation basin.

Chemicals were added to the flocculation basin using positive displacement pumps equipped with either 25 mm (1 in) or 12.7 mm (0.5 in) Viton pump heads. Alum was introduced as far back in the influent line as possible to ensure adequate mixing with the influent before coming into contact with the polymer. The polymer was fed at the point of influent discharge to the flocculation basin. Additional mixing in the flocculation basin was accomplished using a 2.67 kg-Cal/min (0.25 hp) mixer equipped with two 13 mm

(5.2 in) and one 20 mm (7.7 in) propellers on a 1.52 m (5 ft) shaft.

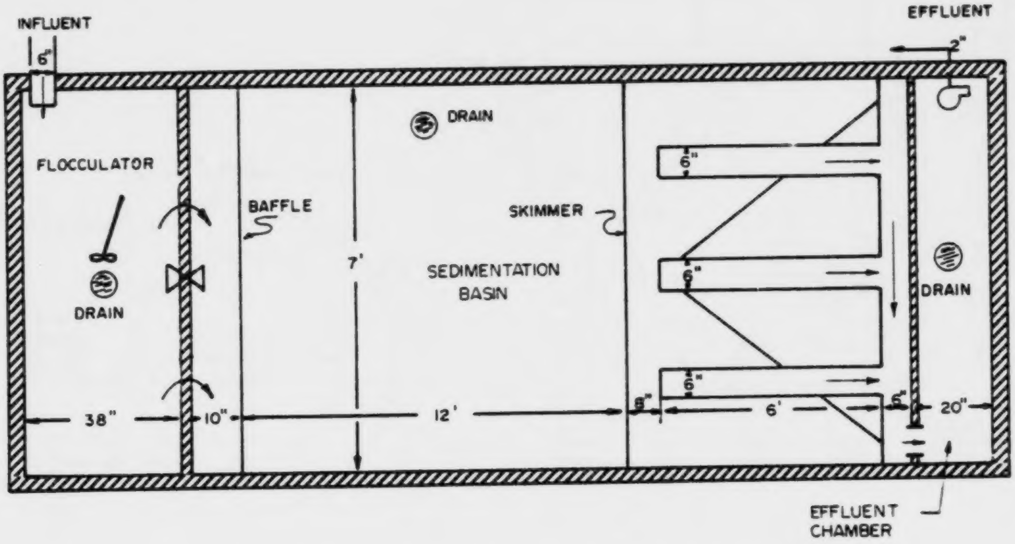


FIGURE 4. Flocculation/ Sedimentation Tank (Pilot Unit)

The major portion of the flocculation/sedimentation effluent was returned to the main sewer system. A portion of this effluent was capable of being directed into the carbon columns, the dual-media filters and disinfection bays. Grab samples were taken from 12.7 mm (0.5 in) taps located on the influent and effluent lines.

SWIRL CONCENTRATORS

The pilot facilities included a swirl degritter and a swirl primary separator connected in series. Dimensions of the swirl degritter, shown on Figure 5, are listed in Table 1. During normal operations the overflow from the swirl degritter (Figure 5) became the influent for the swirl primary separator (Figure 6). Provisions were also made, however, to allow the plant influent to bypass the swirl degritter and go directly into the swirl primary separator.

Both the inlet and outlet pipe diameters associated with the swirl degritter were 15.2 cm (6 in); each was fitted with 12.7 mm (0.5 in) sample taps. Installation of a 10.2 cm (4 in) gate valve on the swirl degritter solids drawoff line permitted the intermittent discharge of any solids which accumulated in the unit.

The dimensions of the swirl primary separator, shown in Figure 6, are listed in Table 1. The inlet pipe diameter, D_1, was 10.2 cm (4 in) and the outlet diameter was 7.6 cm (3 in). Sample taps were located on

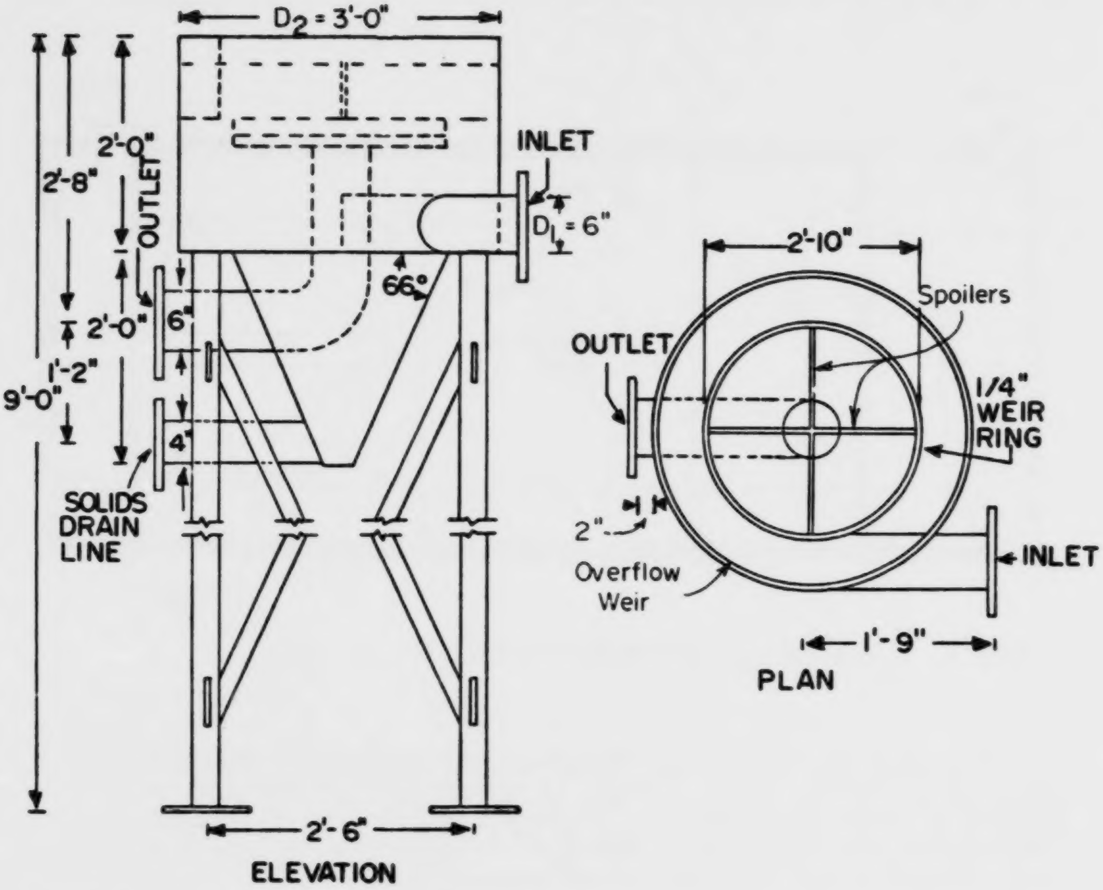

D2 = 3'-0"
INLET
D1 = 6"
2'-0"
2'-8"
OUTLET
66°
6"
2'-0"
1'-2"
9'-0"
4"
SOLIDS DRAIN LINE
2'-6"
ELEVATION
2'-10"
Spoilers
OUTLET
1/4" WEIR RING
2"
Overflow Weir
INLET
1'-9"
PLAN

FIGURE 5. Swirl Degritter (Pilot Unit)

both the influent and effluent lines.

Two methods of sludge drawoff were provided for the swirl primary separator unit: intermittent and continuous. Installation of a 12.7 mm (0.5 in) ball valve on the solids drain line permitted accumulated sludge to be withdrawn intermittently. Continuous drawoff was achieved through a 2.54 cm (1 in) line using the head differential between the swirl unit and the outlet.

Chemical treatments to the swirl primary unit were added using positive displacement pumps. Alum was introduced to the swirl degritter effluent immediately as it exited the overflow weir. Anionic polymer was introduced approximately 1.8 m (6 ft) downstream from the point of alum addition and 2.4 m (8 ft) upstream of the swirl primary unit. A second mode of chemical addition was tested during Storm No. 19. It was attempted to gain enhanced mixing and contact time by adding alum upstream of the swirl degritter--

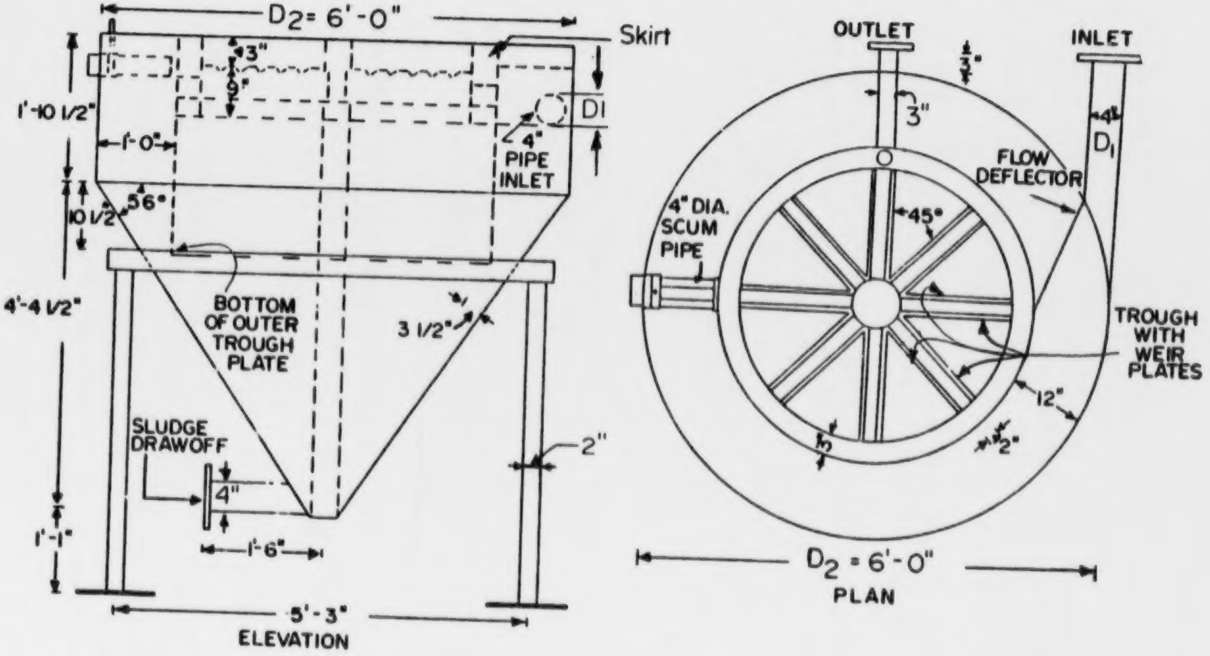

D2= 6'-0"
Skirt
3"
9"
D1
1'-10 1/2"
1'-0"
4" PIPE INLET
10 1/2"
56°
4'-4 1/2"
BOTTOM OF OUTER TROUGH PLATE
3 1/2"
SLUDGE DRAWOFF
4"
2"
1'-1"
1'-6"
5'-3"
ELEVATION
OUTLET
INLET
3"
4"
D1
FLOW DEFLECTOR
4" DIA. SCUM PIPE
45°
TROUGH WITH WEIR PLATES
12"
2"
h
D2 = 6'-0"
PLAN

FIGURE 6. Swirl Primary Separator (Pilot Unit)

converting the degritter to a flocculation basin by installing a mixer.

MICROSCREENING SYSTEM

The microscreening system* used at the pilot plant employed a sonic cleaning mechanism. Figure 7 shows an elevation view of the microscreen and the sonic cleaner. Used in conjunction with the rotating strainer drum, the sonic cleaner provided continuous cleaning of the screen area of 1.83 m^2 (6 ft^2) with a peak hydraulic loading rate of 1221 l/min m^2 (30 gpm/ft^2). This represented a maximum flow rate of approximately 11.4 l/s (180 gpm).

Determination of the headloss across the screens was accomplished through the use of two manometers attached to the outside of the unit.

Both influent and effluent lines were 10.2 cm (4 in) in diameter. Effluent from the unit could be directed back into the main sewer system or into any of the four storage tanks. To prevent the accumulation of solids in the unit during operation, a 25 mm (1 in) flexible hose and ball valve were connected to the solids concentrate drain line. This permitted the drawoff of solids on an intermittent basis in lieu of continuous drawoff.

STORAGE TANKS

The effluents from both the microscreen system and the swirl separators were capable of being stored in quantities of 37.9 m^3 (10,000 gal) each. Four steel tanks, each having a capacity of 18.95 m^3 (5000 gal), were used to provide this storage. This storage permitted the operation of the secondary treatment units for four to five days following the wet-weather event. Figure 8 shows dimensions of the storage tanks used at the plant facilities.

Mixing of the stored CSO in each tank was provided with a 10.68 kg-cal/min (1 hp) mixer to keep the solids in suspension and maintain the D.O. levels above 2 mg/l.

DUAL-MEDIA HIGH-RATE FILTERS

Pilot filter studies were conducted using one PVC and two plexiglass columns. These filter columns were operated in parallel. Each column was 15 cm (6 in) in diameter and 5.5 m (18 ft) in depth. Filter media consisted of 1.5 m (5 ft) of No. 2 anthracite over 0.9 m (3 ft) of No. 1220 sand. Influent to the filter was from the storage tanks containing the effluent from either the microscreen or the swirl separator systems and was delivered through 25 mm (1 in) diameter pipes using 16.02 kg-cal/min (1.5 hp) centrifugal pumps. Similar pumps were employed in transferring the filter effluent to subsequent pilot operations. Flow measurements for both the influent and effluent were obtained using 19 mm (0.75 in) rotameters having a range of 0.13 to 0.63 l/s (2 to 10 gpm). Installation of a float-valve mechanism on the filter discharge facilitated the operation of the filter units. Figure 9 shows dimensions of the filter columns.

---

* supplied by FMC Corporation

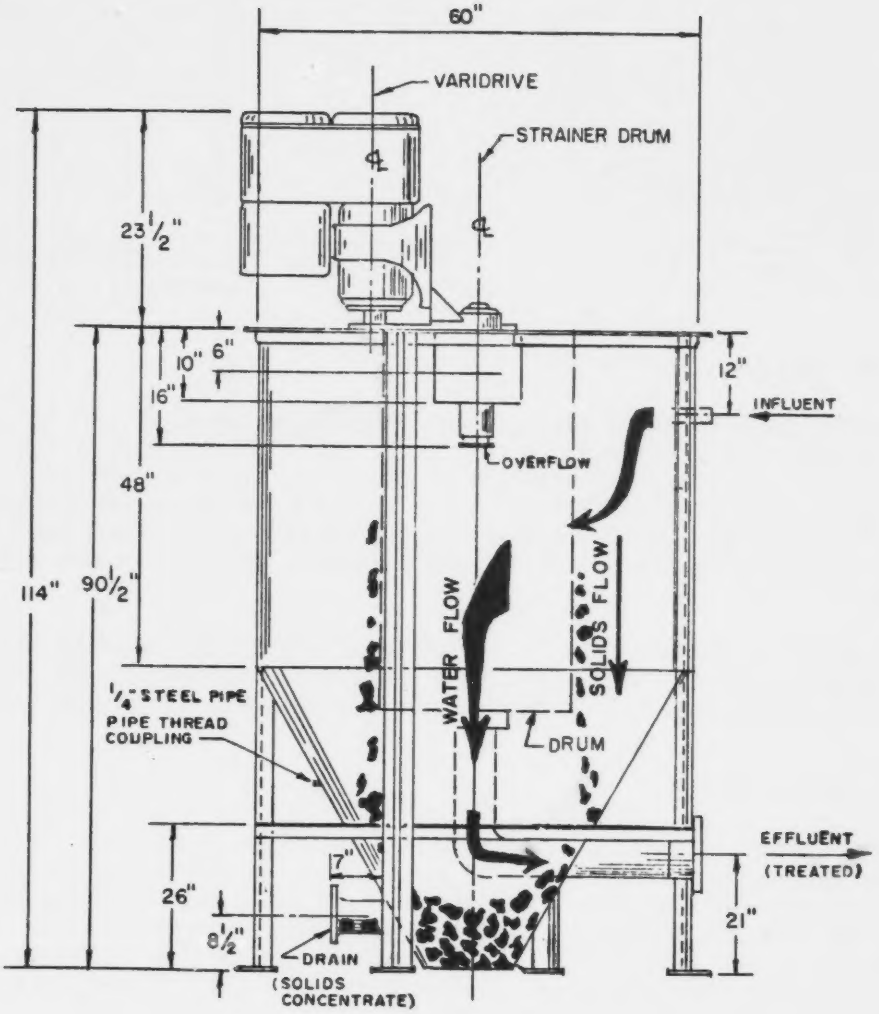

60"
VARIDRIVE
STRAINER DRUM
23½"
6"
10"
16"
12"
INFLUENT
OVERFLOW
48"
114"
90½"
WATER FLOW
SOLIDS FLOW
¼" STEEL PIPE
PIPE THREAD COUPLING
DRUM
EFFLUENT (TREATED)
7"
26"
8½"
21"
DRAIN (SOLIDS CONCENTRATE)

FIGURE 7. The FMC Sonic Cleaner Microscreen (Pilot Unit)

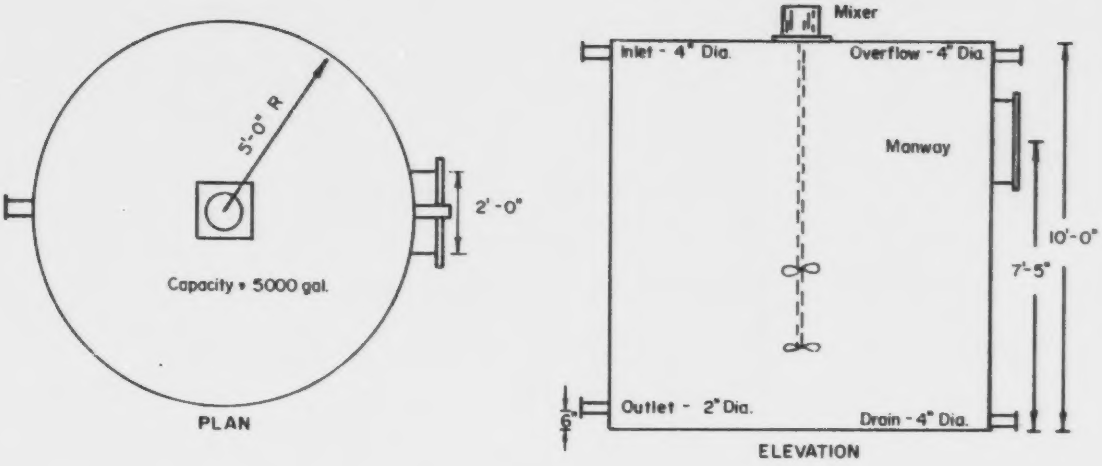


FIGURE 8. Storage Tank

Samples were taken at the influent and effluent ends of the filters and at depths of 0.6 and 1.5 m (2 and 5 ft) below the surface of the filter beds. Headloss measurements across the filters were obtained at depths of 0, 0.6, 1.5, and 2.4 m (0, 2, 5, and 8 ft) below the surface of the filter beds. Upflow backwash of the filters was accomplished by feeding tap water to the bottom of each column. Air scouring was also provided.

Chemical addition to the filter influent was accomplished by utilizing positive displacement pumps. Alum was introduced upstream of the filter feed pumps. Polymer was introduced immediately downstream of the feed pumps.

CARBON ADSORPTION

Three carbon columns were installed at the pilot plant site. Figure 10 shows dimensions of these facilities. The units were sized to accept a portion of the effluent from the flocculation/sedimentation system or the total flow from the dual media filters. The three columns could be arranged in either parallel or series to allow flexibility in testing. Piping following the columns was arranged to allow the effluent to be directed into any of the disinfection bays.

The units were filled with 2.1 m (6.8 ft) of Calgon Filtrasorb 400 granular carbon. This media has an effective size of 0.55 - 0.65 mm, a uniformity coefficient of 1.9 or less, and a bulk density of 400 kg/m^3 (25 lb/ft^3). Backwash facilities were provided by connecting a water line to the bottom of each of the columns.

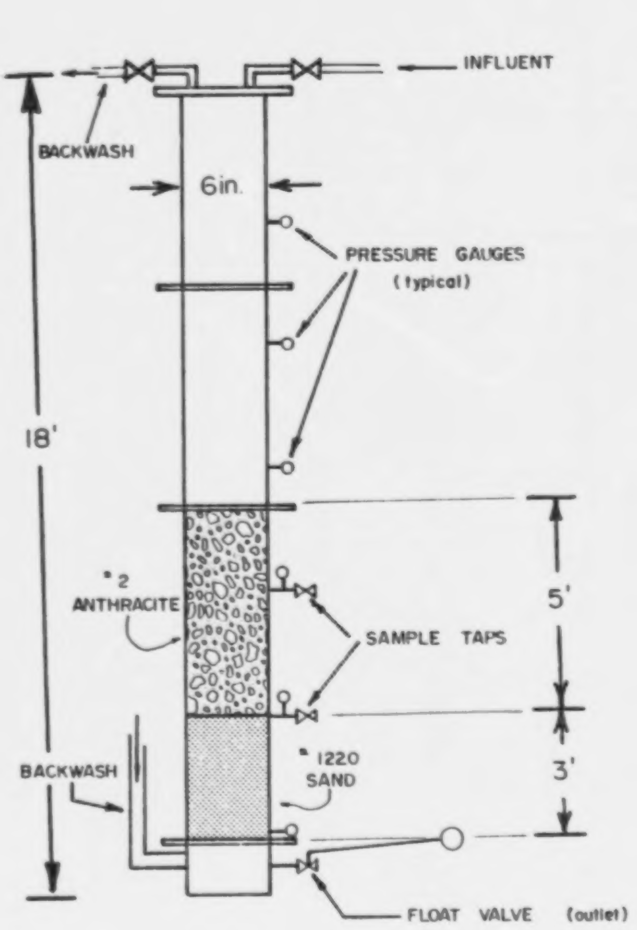

INFLUENT
BACKWASH
6in.
PRESSURE GAUGES
(typical)
18'
#2
ANTHRACITE
SAMPLE TAPS
5'
3'
BACKWASH
#1220
SAND
FLOAT VALVE (outlet)

FIGURE 9. Dual-Media High-Rate Filter (Pilot Unit)

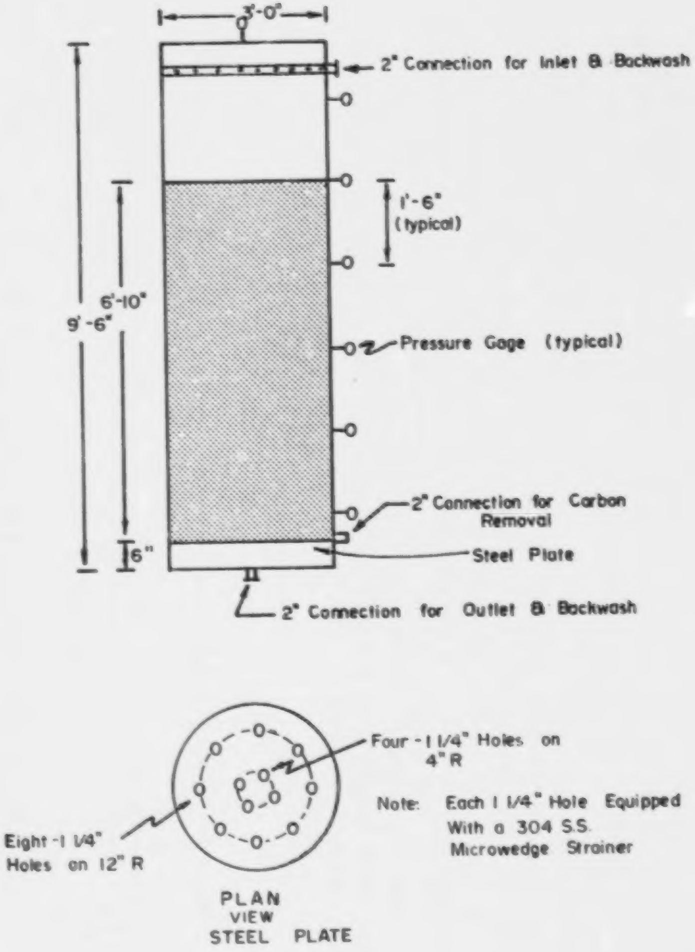

3'-0"
2" Connection for Inlet & Backwash
1'-6"
(typical)
9'-6"
6'-10"
Pressure Gage (typical)
2" Connection for Carbon Removal
6"
Steel Plate
2" Connection for Outlet & Backwash
Four-1 1/4" Holes on 4" R
Eight-1 1/4" Holes on 12" R
Note: Each 1 1/4" Hole Equipped With a 304 S.S. Microwedge Strainer
PLAN VIEW STEEL PLATE

FIGURE 10. Activated Carbon Column (Pilot Unit)

DISINFECTION SYSTEM

Three parallel, high-rate pilot tanks were provided to study disinfection optimization by mixing methods. The mixing techniques included parallel corrugated baffling, sequential flash mixing and single flash mixing at the point of application. These are outlined along with the tank dimensions in Figure 11. Provisions were made to allow each mixing technique to be evaluated in each of the three bays. Flash mixing was furnished by 2.53 kg-cal/min (0.05 hp) mixers equipped with 0.46 m (18 in) shafts and 5 cm (2 in) diameter props. Each mixer delivered a water hp of approximately 0.02. G values were calculated for three components: walls, baffles, and mixers (58). The system G value was defined as $\Sigma GT/\Sigma T$ using the zone of influence for each component. A number of different weir heights were made available for the purpose of evaluating different detention times.

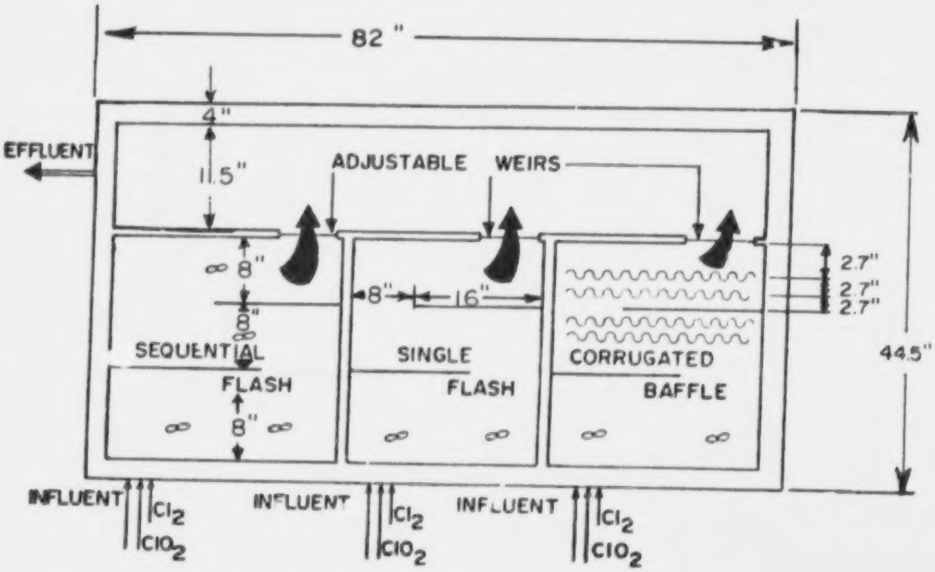


FIGURE 11. Pilot Disinfection Tank and Mixing Concepts Plan View

The disinfectants used were chlorine and chlorine dioxide. Chlorine was supplied in cylinders and chlorinators were used to disperse the chlorine in water prior to dosing. The portion of the chlorine solution applied to the bays was measured manually and samples were withdrawn hourly for determination of solution strength by Iodometric back titration methods (77).

Chlorine dioxide was initially prepared through two chlorine dioxide generators (supplied by Chemical Generators, Inc.). Laboratory testing of chlorine dioxide revealed that low concentrations of the solution would remain relatively stable for a period of 3-4 days if kept in a closed container. This made it possible to manually prepare sufficient quantities of the solution in advance of any disinfection testing. The chlorine dioxide was fed into the bays using pumps having a capacity of 17 ml/min (0.004 gpm). Application rates were measured volumetrically. Strength of the chlorine dioxide solution was determined using Starch-Iodide (77) or DPD titration techniques (50).

SECTION 5

PROJECT PLAN

PROGRAM DEVELOPMENT AND APPLICATION OF RESULTS

The Rochester CSO study program included overflow sampling and monitoring, sewer network modeling, and pilot plant testing of the CSO treatment alternatives. The pilot plant studies were designed to interface with the mathematical modeling for evaluation of abatement alternatives.

The system modeling generally employed the EPA-developed Stormwater Management Model (SWMM). One of the components of this model is a Storage-Treatment block which provides estimates of treatment efficiency for time-variable storm flows for specified process train selections and design conditions.

The test programs and development of performance equations were directed toward evaluating the effects of varying hydraulic loadings and influent quality on the performance of the treatment systems. The effects of chemical treatments are also included, where applicable. The performance models, coupled with cost developments were used to compile cost/benefit comparisons and design optimizations of some of the alternatives. Opportunities for such optimizations generally arise because of the relative infrequent use of the wet-weather treatment facilities. These optimizations may indicate the possibilities of achieving greater economies by employing procedures that may increase the operating cost (e.g. high chemical doses or high energy mixing) by permitting great reductions in sizing of facilities and the capital costs. The operating costs for wet-weather facilities represent a much lower fraction of total yearly costs than the cost for dry-weather plants. These optimizations are highly dependent on site-specific factors such as number of overflows and the total quantity of overflows to be treated per year.

The cost and performance relationships were also used to evaluate a number of area-wide alternatives. These alternatives are presented in Volume I of this report (3). The alternatives included: a) optimizations of storage versus treatment sizing, b) use of local satellite treatment plants versus centralized treatment, c) alternative locations of centralized treatment, and d) use of satellite treatment for first-flush overflows only, with collection of remaining flows.

SCOPE OF WORK

Pilot operations covered nineteen overflow events during the period of September 1975 through June 1976. Storm characteristics associated with these storms are listed in Table 2. The piloted processes included flocculation/sedimentation, swirl degritter and swirl primary separator, microscreening, dual-media high-rate filtration, activated carbon adsorption and high-rate disinfection. While these include some of the major processes generally considered for CSO treatment, there are other alternatives that were not piloted. For example, dissolved air flotation, biological lagoons, and rotating biological discs have been studied by others for application to CSO treatment. It was also not intended to comprehensively evaluate all design parameters associated with each system. The sampling and operation schedules were established to permit evaluations of variable influent quality and the effects of the selected operating conditions. Analyses included evaluations of BOD_5, SS, VSS, total solids, volatile solids, setteable solids, COD, TOC, total inorganic phosphorus, TKN, oil and grease, temperature, metals, and fecal coliforms. All analyses were conducted in accordance with Standard Methods (77) and/or Methods for Chemical Analysis of Water and Wastes (78).

In addition to the pilot plant process operations, a number of support studies were included throughout the program. These included dry weather testing of the unit processes, determination of reaction rates in the ClO_2 generator, determinations of alum and polyelectrolyte dosage requirements, sludge thickening and dewaterability testing, particle size distributions and specific gravities, and analyses of heavy metals content of influents, treated effluents, and sludges.

TABLE 2. STORM CHARACTERISTICS

Storm No.	Date	Rainfall Start Time	Rainfall Duration (hrs.)	Total Rainfall (inches)	Pilot Plant Startup Time	Overflow Duration (hrs.)	Peak Overflow Rate (MGD)
1	09/25/75	1600	6.0		1840	5.25	
2	10/09/75	1345	6.6		1810	2.7	
3	10/17/75	1815	7.2		2100	6.75	
4	11/10/75	0630	4.0	0.22	0830	3.0	7.0
		1255	0.7	0.30	1310	1.6	12.1
5	11/21/75	0400	5.8	0.50	0815	3.7	7.0
6	12/06/75	0715	2.5	0.60	0830	2.25	10.6
7A	12/09/75	1130	2.3	0.25	1255	1.1	5.7
7B	12/09/75	2100	9.0		2255	7.5	6.8
8	01/26/76	0400	8.5		0930	14.0	
9	02/18/76	0200	7.0		0730	5.0	
10	02/18/76	2030	2.25	0.15	2115	2.4	30.0
11	02/21/76	1230	4.5		1315	2.0	30.0
12	03/03/76	0315	6.25	0.45	0530	11.75	30.0
13	03/12/76	1400	2.25	0.30	1500	2.0	10.0
14	03/19/76				0920	7.7	10.0
15	03/31/76	1140	3.2	0.60	1215	3.9	50.0
16	04/21/76	1620	2.6	0.50	1615	2.7	50.0
17	05/11/76	1130	4.5	0.25	1335	3.5	12.0
18	05/19/76	1145	13.5	1.51	1250	14.5	30.0
19	06/21/76	1830	2.0		1900	1.8	

SECTION 6

FLOCCULATION/SEDIMENTATION

BACKGROUND

Primary sedimentation of raw municipal wastewater has been applied conventionally at overflow rates (OR) of 24 to 41 m^3/day m^2 (600 to 1000 gpd/ft^2). Typically, suspended solids removal rates of 30 to 60 percent are attained in this process.

The OR is the single most important design criteria for sizing of sedimentation basins (6, 7, 8). Theoretically, depth and detention time have minor influence on determining removal efficiencies for discrete particles. However, for flocculent particles, detention time plays a more important role since settling velocity increases with time of particle agglomeration. In practice, minimum depths and detention times are employed based on experience.

OR is an expression of the upflow hydraulic velocity created in the basin. Particles with settling velocities greater than the upflow velocity will be removed. In combined sewer overflows the particle size distribution is considerably coarser than in typical dry weather flow, since the high scour velocities created in the sewer suspend larger particles. It would be expected, then, that OR's applicable to treatment of CSO might be considerably higher than those applied to dry-weather flow.

The effects of OR on SS removals from municipal wastewater have been evaluated by several investigators. The ASCE Manual of Engineering Practice Number 36 (71) includes a design curve for selecting OR for a desired removal efficiency. This is shown on Figure 18. Smith (72) presented a similar evaluation from analysis of field data and developed the performance function:

$$\text{SS Removal Efficiency (\%)} = 82\, e^{-(OR/2780)}$$

This equation shown on Figure 18 closely approximates the ASCE curve. Both relationships above were basically developed for municipal dry-weather flows.

An analysis of operating data for primary facilities at Los Angeles (9) evaluated OR's as high as 163 m^3/day m^2 (4000 gpd/ft^2). These results indicated that major losses in performance were not experienced until OR was increased beyond about 82 m^3/day m^2 (2000 gpd/ft^2) (see Figure 18). One of the major reasons why such high OR's were attainable might have been the relatively high influent SS concentration (average 500 to 600 mg/l) in the raw wastewater. This might indicate a relatively coarse solids size distribution. This study also indicated that performance was not influenced by flow-through velocities, v, less than 1.2 m/min (4 fpm), but sludge resuspension became significant at levels above 1.2 m/min (4 fpm). Camp (7) has stated that velocities up to 5.5 m/min (18 fpm) may not cause resuspension, however, designs should incorporate velocities substantially under 5.5 m/min (18 fpm). Other tests at Los Angeles (10) showed that velocities above 1.8 m/min (6 fpm) did not hinder removals when alum and polyelectrolyte were employed. The selected velocity influences the configuration of the basin, high velocities being associated with shallow and narrow basins. Below the scour velocity, high velocities tend to enhance velocity gradient flocculation (11).

Data from full-scale primary facilities treating sanitary and wet-weather combined sewage at Toronto, Canada, has also been published (12). These data, covering a range of influent SS from 287 to 627 mg/l, show significant removals at OR's up to 82 m^3/day m^2 (2000 gpd/ft^2). Removals are shown to be related to influent SS concentration, indicating the impact of the coarser particle size distribution associated with the higher SS levels.

OUTLINE OF EXPERIMENTS

A high-rate sedimentation system has been designed for treatment of wet-weather flows from the Rochester Pure Waters District (13). The facility is proposed to consist of four units with a total capacity of 1041 m^3/day (275 mgd). Dimensions of each unit are 117 m (384 ft) x 32.5 m (106.5 ft) x 4.7 m (15.5 ft) deep. Design parameters included maximum OR of 81.6 m^3/day m^2 (2000 gpd/ft^2), detention time of 75 min and flow-through velocity of 1.22 m/min (4.0 ft/min).

The primary sedimentation basin at the pilot plant was intended to evaluate the chemicals necessary to achieve phosphorous removal through the flocculation/sedimentation process. However, due to the detergent ban in New York State, the levels of phosphorous observed in Rochester CSO have generally been less than 1 mg/l as P even under peak conditions. These low levels of phosphorous preclude the need for phosphorous removal as applied to the Rochester CSO.

Alum treatment is incapable of producing phosphorous levels significantly below those observed. Therefore, chemical treatment (alum and/or polymers) was evaluated mainly from the standpoint of enhancement of suspended solids removal. However, a limited amount of testing was included whereby the influent was spiked with phosphate and the alum dosage adjusted for phosphorous removal.

The matrix of tests employed in the program is outlined in Table 3.

The pilot plant tests included evaluations of the effect of OR under four chemical treatment programs. The chemical treatments included: no chemical addition, polyelectrolyte only, alum + polyelectrolyte, and phosphorous spiking accompanied by higher alum and polyeletrolyte doses. Selection of the chemical treatments is discussed in subsequent pages.

TABLE 3. FLOCCULATION/SEDIMENTATION SYSTEM TEST MATRIX

Storm No.	Pilot Flowrate (gpm)	OR (gpd/ft^2)	d.t. (min.)	v (fpm)	P-Spike (mg/l)	Alum (mg/l)	Polymer (mg/l)
1	71	800	38.8	0.8			
2	71	800	38.8	0.8			
3	133	1500	15.7	2.3			
4	124	1407	16.7	2.3			
5	165	1870	15.2	2.2			
6	165	1870	15.2	2.2			
7A	177	2000	14.2	2.2			
7B	162	1830	15.6	2.0			
8	71	800	78.0	0.24			
9	133	1500	42.0	0.45			
10	177	2000	31.0	0.59			
11	71	800	78.0	0.24			1.0
12	133	1500	42.0	0.45			1.0
13	177	2000	31.0	0.59			1.0
14	177	2000	31.0	0.59			
15	71	800	78.0	0.24		40	1.0
16	133	1500	42.0	0.45		40	1.0
17	177	2000	31.0	0.59		40	1.0
18	71	800	78.0	0.24	2.13	105	1.0
19	177	2000	31.0	0.59	0.85	105	1.0

The matrix of tests also included evaluations of OR's of 33, 61 and 82 m^3/day m^2 (800, 1500 and 2000 gpd/ft^2). OR was held constant throughout the duration of each storm to study the system efficiency under variable influent solids concentrations. It was considered necessary to evaluate the performance relative to CSO quality, since some of the area-wide abatement alternatives considered the use of facilities for treatment of the first-flush storm component only.

Sludge withdrawal was not employed with any of the tests. Calculations indicated that sludge accumulation for an average storm of 4 hours duration would result in an accumulation of less than two inches of sludge. The sludge layer was sampled at the termination of each test.

Weir overflow rates (WOR) of 84, 63 and 33 m^3/day m^2 (6800, 5100 and 2700 gpd/ft) of weir were employed at OR's of 33, 61 and 82 m^3/day m^2 (800, 1500 and 200 gpd/ft^2) respectively, which were low enough to prevent exit losses of suspended particles.

The 2.67 kg-cal/min (0.25 hp) agitator employed in the flocculation basin imparted a velocity gradient (G) of approximately 120 sec^{-1}. This resulted in mixing intensities (GT) of 42,000 to 104,000, values typically associated with flocculation systems.

CHEMICAL TREATMENT REQUIREMENTS

In order to select the types and dosages of chemicals to be employed in the pilot tests, a number of laboratory jar tests were conducted using Rochester CSO. A range of polyelectrolyte types were tested in conjunction with an alum dosage of 50 mg/l. Figure 12 indicates the comparison of the performance of several polyacrylamides based on the charged functional groups. These data indicate increasing performance with increasing anionic content of the polyelectrolyte. A highly anionic polyacrylamide (Nalcolyte 676) was selected for use in all testing at the pilot facilities.

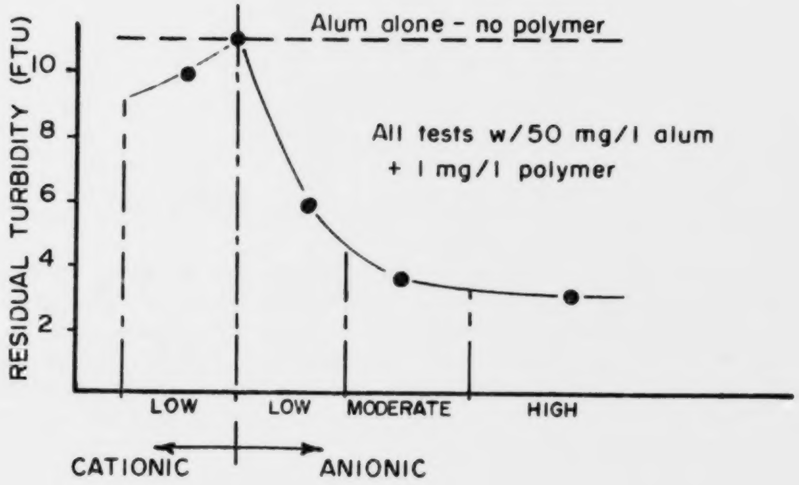


FIGURE 12. Comparison of Polyelectrolyte Types

The same trend was verified when the data of Nebolsine, et al. (14) were evaluated. That report presented the results of filtration of CSO when employing a variety of polyelectrolytes from many suppliers. When compared on the basis of charged functional groups it was again noted that flocculation of CSO responded best to highly anionic polyelectrolytes.

The effect of polyelectrolyte dosage is indicated on Figure 13. A typical dosage of 1.0 mg/l was anticipated to provide optional flocculation, and was verified by this test.

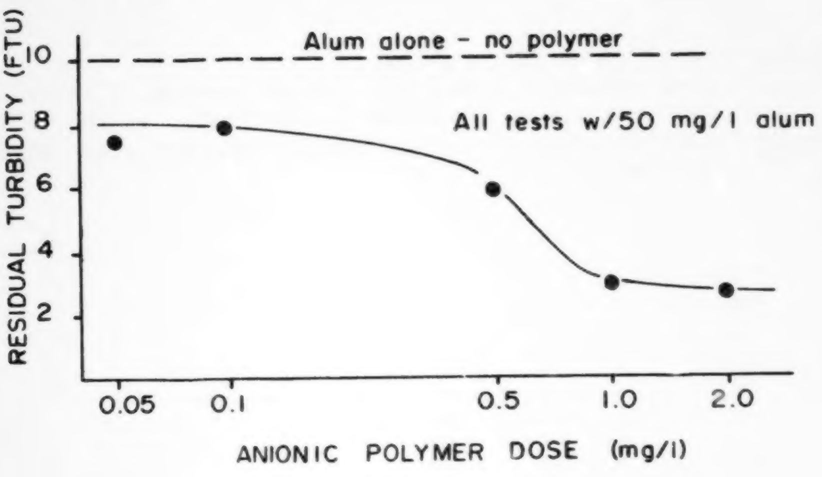


FIGURE 13. Selection of Polyelectrolyte Dosage

Alum dosage requirements were established by testing samples of CSO taken during several intervals throughout a storm. Figure 14 shows test results when several alum doses were tested on each CSO sample. It is noted that for all portions of the storm, optimal results were attained with an alum dosage of approximately 40 mg/l.

SUSPENDED SOLIDS REMOVAL

Appendix B presents the results of the SS analysis of influent and effluent data for the flocculation/sedimentation basin. These plots indicate results as the samples were taken, and are not adjusted for the detention time in the unit. From these curves, influent data were lagged by the theoretical detention time in the treatment unit and SS removal rates were calculated for each 20 minute increment. Multiple regression analysis was then conducted between the SS removal rates, surface overflow rate, and the concentration of influent suspended solids for three chemical treatment conditions. A statistical fit to the pilot plant data was obtained in the form of the following equation:

$$\text{Log } (c_e/c_o) = K_1 + K_2 \log Q + K_3 \log c_o$$

where

c_e/c_o = fraction of SS remaining
Q = flow through the flocculation/sedimentation basin (gpm)
c_o = influent suspended solids concentration in the unit (mg/l)
K_1, K_2, K_3 = regression coefficients representing different chemical treatments

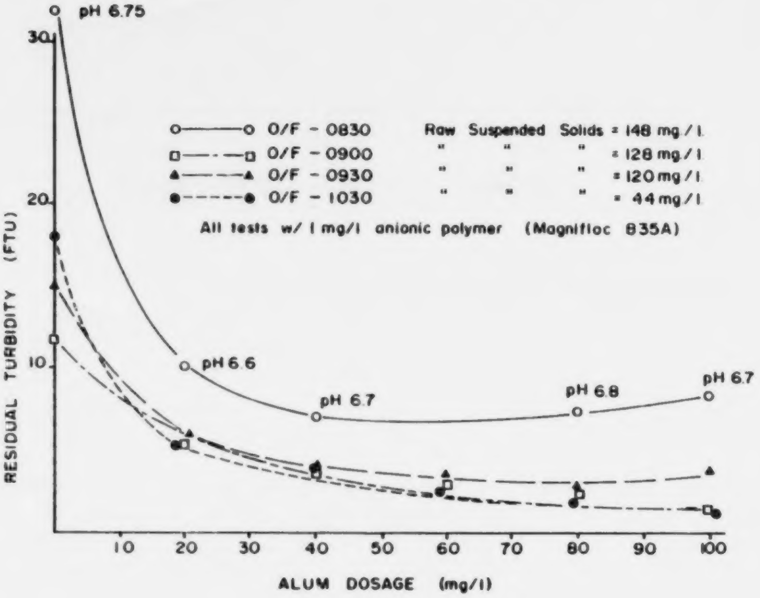


FIGURE 14. Variation in Alum Demand

Results of the regression analyses are indicated in Tables 4, 5, and 6. In all three cases the regression coefficients indicated the following trends: (a) percent removal of SS decreases as the hydraulic loading to the system increases and (b) percent removal of SS increases as the influent SS concentration increases. The magnitude of the regression coefficients associated with hydraulic loadings in all cases indicate a fairly minor effect of applied flowrate within the test range on SS removals; 'T' values (measure of the statistical significance of the regression coefficients) associated with the flowrate data indicate degrees of confidence of > 99, 75 and 55 percent, respectively, for treatments of no chemicals, polymer only and alum plus polymer. The influent concentration of SS has a major effect on the percentage removal of SS; 'T' values associated with the influent SS data in all cases represent degrees of confidence greater than 99 percent.

The performance equations were derived from the regression analysis by providing the conversion OR = Q x 11.3.

For no chemical treatment:

$$\log (c_e/c_o) = 1.71 + 0.072 \log Q - 0.836 \log c_o$$

$$c_e/c_o = 43.4 \ (OR)^{0.072} \ (c_o)^{-0.836}$$

For treatment with anionic polymer:

$$\log (c_e/c_o) = 1.20 + 0.175 \log Q - 0.806 \log c_o$$

$$c_e/c_o = 10.3 \ (OR)^{0.175} \ (c_o)^{-0.806}$$

For treatment with alum plus anionic polymer:

$$\log (c_e/c_o) = 0.765 + 0.193 \log Q - 0.775 \log c_o$$

$$c_e/c_o = 3.63 \ (OR)^{0.193} \ (c_o)^{-0.775}$$

where c_e = effluent SS concentration (mg/l), c_o = influent SS concentration (mg/l), Q = applied pilot plant flowrate (gpm) and OR = overflow rate (gpd/ft^2).

TABLE 4. MULTIPLE REGRESSION ANALYSIS OF FLOCCULATION/SEDIMENTATION DATA: NO CHEMICAL TREATMENT

Variable	Mean	Standard Deviation	Correlation X vs Y	Regression Coefficient	Std. Error of Reg. Coef.	Computed T Value
Log Q	1.07	1.054	-0.131	0.072	0.010	7.08
Log c_o	2.45	0.225	-0.855	-0.836	0.048	-17.4
Dependent						
Log (c_e/c_o)	-0.260	0.173				

Intercept	1.71
Multiple Correlation	0.934
Std. Error of Estimate	0.063

Analysis of Variance for the Regression

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F Value
Attributable to Regression	2	1.23	0.618	154.8
Deviation from Regression	45	0.179	0.0039	
Total	47	1.41		

TABLE 5. MULTIPLE REGRESSION ANALYSIS OF FLOCCULATION/SEDIMENTATION DATA: TREATMENT WITH ANIONIC POLYMER

Variable	Mean	Standard Deviation	Correlation X vs Y	Regression Coefficient	Std. Error of Reg. Coef.	Computed T Value
Log Q	2.16	0.118	0.496	0.175	0.146	1.19
Log c_o	2.42	0.220	-0.908	-0.908	0.078	-10.2
Dependent						
Log (c_e/c_o)	-0.373	0.206				

Intercept	1.20
Multiple Correlation	0.912
Std. Error of Estimate	0.086

Analysis of Variance for the Regression

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F Value
Attributable to Regression	3	1.13	0.566	74.9
Deviation from Regression	30	0.226	0.0075	
Total	32	1.36		

TABLE 6. MULTIPLE REGRESSION ANALYSIS OF FLOCCULATION/SEDIMENTATION DATA: TREATMENT WITH ALUM AND ANIONIC POLYMER

Variable	Mean	Standard Deviation	Correlation X vs Y	Regression Coefficient	Std. Error of Reg. Coef.	Computed T Value
Log Q	2.00	0.172	0.197	0.193	0.244	0.792
Log c_o	2.443	0.253	-0.675	-0.775	0.166	-4.667
Dependent						
Log (c_e/c_o)	-0.741	0.298				

Intercept	0.765
Multiple Correlation	0.684
Std. Error of Estimate	0.225

Analysis of Variance for the Regression

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F Value
Attributable to Regression	2	1.20	0.603	11.8
Deviation from Regression	27	1.37	0.050	
Total	29	2.57		

The regression equations are plotted on Figures 15, 16 and 17. Also plotted on these Figures are the experimental results for the test series at hydraulic loadings of 33, 61 and 82 m^3/day m^2 (800, 1500 and 2000 gpd/ft^2). It is noted that the chemical treatments result in significantly enhanced SS removals at all influent SS concentrations. It is also noted that only minor performance losses are incurred by raising the overflow rates from 33 to 82 m^3/day m^2 (800 to 2000 gpd/ft^2). This indicates that overflow rates greater than 82 m^3/day m^2 (2000 gpd/ft^2) should be evaluated, especially with the chemical treatments. It should be emphasized that the performance equations apply to only OR's up to 82 m^3/day m^2 (2000 gpd/ft^2) and influent SS concentration up to 800 mg/l. Results outside of these ranges should not be extrapolated.

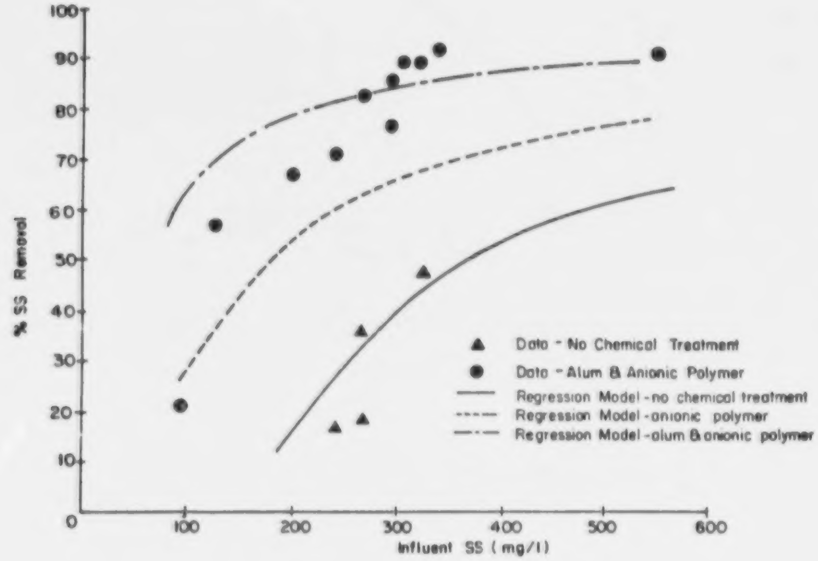


FIGURE 15. Performance of Flocculation-Sedimentation System @ 800 gpd/ft^2

SCALEUP CONSIDERATIONS

Camp (7, 47) has presented a comprehensive consideration of factors involved in scaleup of the design of sedimentation systems. While overflow rate is the most important design parameter, a number of other design factors affect performance, particularly when dealing with flocculent suspensions. For example, flocculation is affected by detention time, differences in particle settling velocities, and velocity gradients in the liquid. Turbulence due to density currents or high velocities can retard settling or result in scour from the bottom. Entrance and exit designs also affect performance. Camp (7) has demonstrated that the degree of short-circuiting in a basin is a function of the Froude number of the horizontal flow. Thus there may be some rationale for the application of Froude Law scaling relationships. However, neither scaleup by

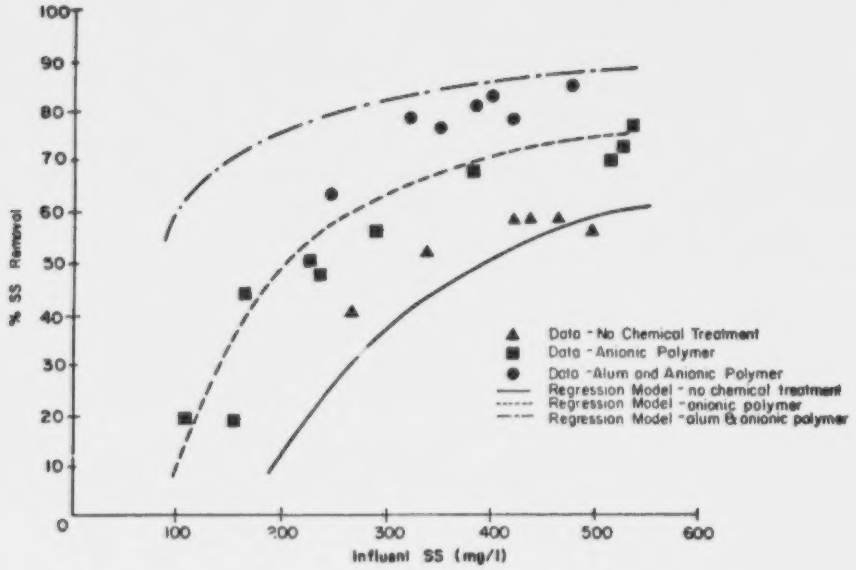


FIGURE 16. Performance of Flocculation/Sedimentation System @ 1500 gpd/ft^2

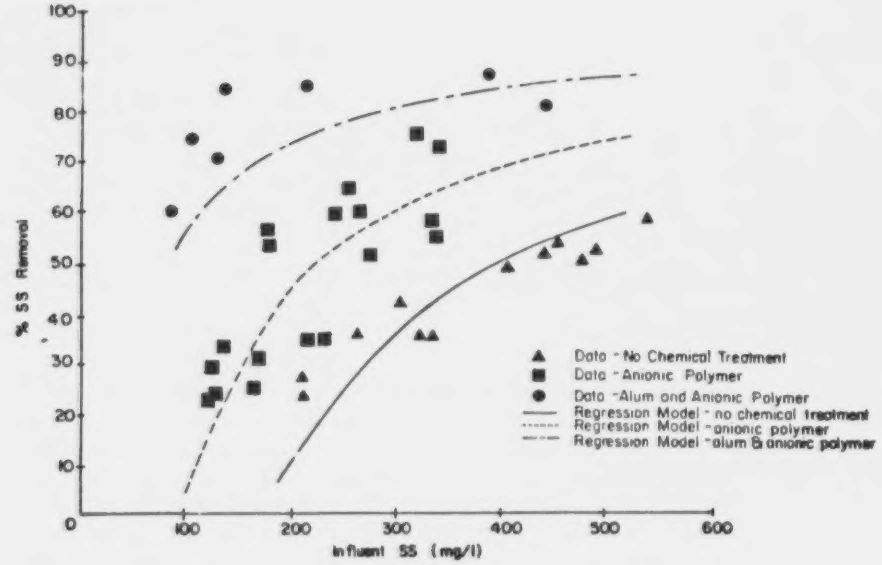


FIGURE 17. Performance of Flocculation/Sedimentation System @ 2000 gpd/ft^2

overflow rate nor Froude Law take into account the effect of detention time on flocculation.

Figure 18 presents a comparison of loading-performance relationships derived from several sources. Some commonly accepted relationships for domestic sewage are illustrated for comparison. Results of treatment of CSO at the Humber plant in Toronto (12) are shown (six primary tanks 34 ft x 327 ft x 10 ft deep). Results were presented for several OR's and for different storm intervals. The influent SS concentrations covered a range from 287 to 627 mg/l. Removals predicted by regression analysis of the Rochester data are presented for the same range of influent SS concentration. All data apply to treatment without chemicals. At the higher loading rates, performance results in Toronto and Rochester were similar, while treatment at the lower loading rates were slightly better for Toronto CSO.

Also indicated on Figure 18 are removals predicted from Rochester CSO particle size analyses (see Section 6). Actual SS removals are in agreement with the removals expected from the calculated particle settling velocities.

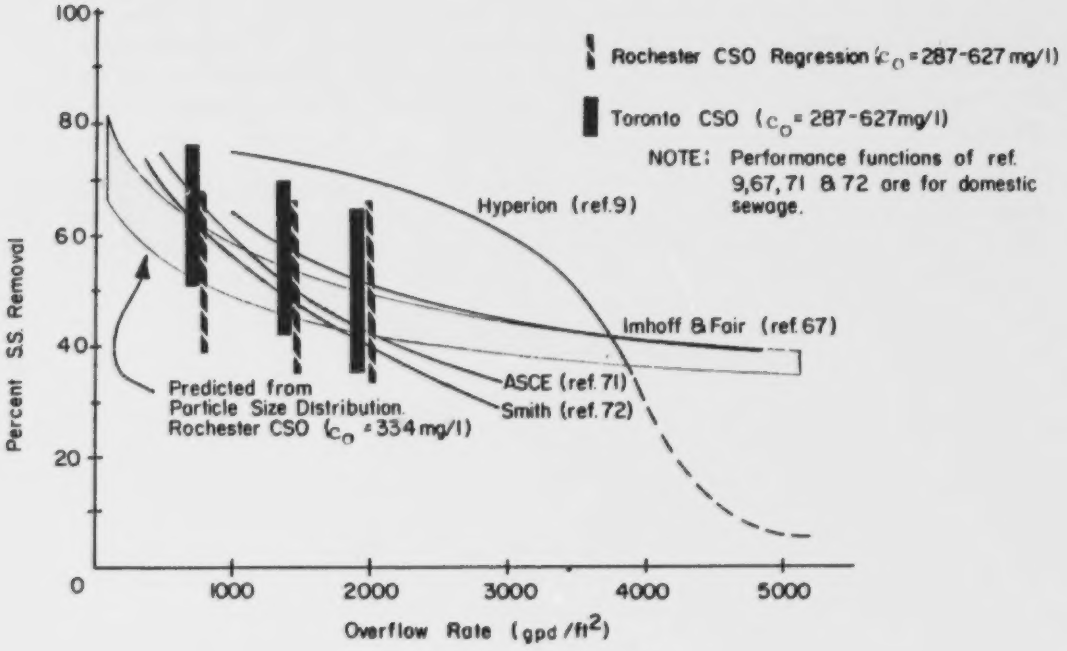


FIGURE 18. Loading-Performance Relationships: Flocculation/Sedimentation System

REMOVAL OF OTHER CONSTITUENTS

Removals of other parameters were evaluated on a storm-average basis. Listings of minimum, maximum, arithmetic means, geometric means and standard deviations of influent and effluent data are included in Appendix B. Table 7 represents the geometric mean or median data for each storm and parameter tested in Rochester, N.Y.

VSS removals were generally higher than the corresponding SS removals. Average VSS removals were 37 percent without chemical treatment, 47 percent with the addition of polymers and 79 percent with alum and polymers. Settleable solids removals were 52, 58 and 94 percent for no chemical treatment, polymer addition, and alum + polymer treatment, respectively.

BOD_5 removals also showed an increase with chemical addition. Median removals were 21 percent for no chemical treatment, 37 percent with polymer addition,and 61 percent for alum + polymer treatment. Average TOC removals were 11, 29 and 47 percent for the above three chemical treatments respectively. Oil and grease removals were 27 percent without chemicals and 35 percent with the addition of alum plus polymer. The effluent pH values ranged from 5.9 to 7.8 without alum, and 5.4 to 7.5 when alum was used.

No appreciable TKN removals were observed in the F/S system under each of the three treatment conditions. TIP removals average 8 percent with no chemical treatment, 11 percent with polymer addition, 71 percent with alum (40 mg/l) and polymer, and 71 percent when phosphorous was spiked (1-2 mg/l as P) and an alum dose of 105 mg/l was used in conjunction with polymer.

Table 8 shows the percent VSS of SS for influent and effluent samples from the F/S system. Mean percentage of VSS in the CSO for all storms was 48.6 and 38.6 percent for effluent samples; 84 percent of the storms showed a decrease in percent VSS for the effluent samples.

TABLE 7. FLOCCULATION/SEDIMENTATION SYSTEM: MEDIAN REMOVALS

Storm No.	SS Data (mg/1) Median Infl.	SS Data (mg/1) Median Effl.	SS Data (mg/1) % Removal	VSS Data (mg/1) Median Infl.	VSS Data (mg/1) Median Effl.	VSS Data (mg/1) % Removal	SETTS Data (mg/1) Median Infl.	SETTS Data (mg/1) Median Effl.	SETTS Data (mg/1) % Removal	BOD_5 Data (mg/1) Median Infl.	BOD_5 Data (mg/1) Median Effl.	BOD_5 Data (mg/1) % Removal
1	132.29	236.16	-78.52	24.98	32.00	- 28.10				7.82		
2												
3	137.72	122.49	11.06	58.98	48.43	17.89	2.64	94	64.39	29.63	35.68	- 20.42
4	164.65	194.13	-17.90	92.09	75.11	18.44						
5	71.13	93.98	-32.12	31.44	82.41	-162.12				340.97	500.07	- 46.66
6	87.75	123.36	-40.58	49.84	46.34	5.02	1.83	1.61	12.02	20.58	13.86	32.65
7A	262.38	223.14	14.96	158.19	87.59	44.63	5.36	2.81	47.57	82.47	78.63	4.66
7B	74.42	50.33	32.37	46.44	15.89	65.78	.41	.24	41.46	21.74	19.96	8.19
8	189.12	197.30	- 4.33	105.67	57.51	45.58	2.13	1.04	51.17	71.46	88.58	- 23.96
9	302.58	180.10	40.48	158.54	80.53	49.21	1.71	.15	91.23	30.18	23.38	22.53
10	190.48	229.44	-20.45	83.65	86.46	- 3.36	1.24	.54	56.45	51.32	42.25	17.67
11	171.35	120.88	29.45	85.84	57.99	32.44	1.55	.92	40.65	37.27	25.86	30.61
12	266.01	112.06	57.87	146.04	54.40	62.75	2.52	.81	67.86	77.82	32.52	58.21
13	195.49	119.97	38.63	132.12	70.08	46.96	4.00	1.41	64.75	102.25	79.97	21.79
14	330.72	199.71	39.61	133.59	67.89	49.18	6.73	1.76	73.85	135.12	83.92	37.89
15	449.56	34.67	92.29	162.15	6.65	95.90	7.10	.13	98.17	121.37	30.40	74.95
16	445.37	74.50	83.27	155.25	26.64	82.84	1.40	.26	81.43	48.71	27.73	43.07
17	162.52	50.98	68.63	79.20	17.60	77.78	8.45	.19	97.75	126.26	64.76	48.71
18	151.82	55.60	63.38	74.12	13.40	81.92	5.88	.10	98.30	71.43	19.74	72.36
19	183.59	59.21	67.75	41.05	17.55	57.25	2.24	.10	95.54	35.58	11.24	68.41

(continued)

TABLE 7. (continued)

Storm No.	COD Data (mg/l) Median Infl.	COD Data (mg/l) Median Effl.	COD Data (mg/l) % Removal	TOC Data (mg/l) Median Infl.	TOC Data (mg/l) Median Effl.	TOC Data (mg/l) % Removal	O&G Data (mg/l) Median Infl.	O&G Data (mg/l) Median Effl.	O&G Data (mg/l) % Removal	pH Data Median Infl.	pH Data Median Effl.
1	7.93	10.23	-29.00	16.87	20.07	-18.97	9.34	21.00	-124.84	6.18	6.04
2	28.23	32.74	-15.98	48.22	42.93	10.97	28.92	9.90	65.77	5.72	5.90
3	97.00			20.45	19.99	2.25	24.19	24.04	.62	5.90	6.02
4											
5		37.65		109.67	94.53	13.81	20.36	6.86	66.31	6.21	6.63
6	25.41	27.95	-10.00	30.55	29.12	4.68	1.27	1.33	-4.72	6.80	6.19
7A	54.04	55.53	-2.76	61.66	60.91	1.22				7.07	7.26
7B	25.42	24.77	2.56	14.15	14.25	-.71				7.02	7.13
8	86.49	155.79	-80.12	48.31	48.36	-.10				6.51	6.44
9	11.04	12.99	-17.66	31.39	28.55	9.05				7.17	7.40
10	15.69	24.35	-55.19	44.01	39.75	9.68				7.16	7.04
11				26.27	16.72	36.35				8.09	7.85
12				30.59	21.44	29.91				6.68	6.76
13				60.46	48.66	19.52	64.17	63.96	.33	7.00	7.00
14				114.47	72.70	36.49	46.67	33.33	28.58	7.63	7.78
15				55.94	30.88	44.80	41.55	8.64	79.21	7.20	7.50
16				47.71	26.87	43.68	27.41	14.07	48.67	7.12	6.99
17				67.29	28.75	57.27	38.48	76.39	-98.52	6.86	7.09
18				44.90	26.56	40.85	50.87	51.54	-1.32	6.97	5.41
19				19.16	11.70	38.94	54.39	51.94	4.50	7.61	6.82

(continued)

TABLE 7. (continued)

Storm No.	TKN Data (mg/l) Median Infl.			TIP Data (mg/l) Median Infl.			Aluminum Data (mg/l) Median Infl.		
	Median Infl.	Median Effl.	% Removal	Median Infl.	Median Effl.	% Removal	Median Infl.	Median Effl.	% Removal
1	.29	.63	-117.24	.10	.12	- 20.00			
2	2.63	3.18	- 20.91	.24	.33	- 37.50			
3	1.10	1.44	- 30.91	.26	.24	7.69			
4									
5	6.20	5.98	3.55	1.49	1.29	13.42	1.67	2.16	- 29.34
6	2.50	2.29	8.40	.55	.55	.00	2.28	2.11	7.46
7A	4.57	5.16	- 12.91	.63	.71	- 12.70	.60	1.45	-141.67
7B	1.22	1.36	- 11.48	.18	.23	- 27.78	.50	.46	8.00
8	3.05	3.85	- 26.23	.42	.84	-100.00	1.09	1.27	- 16.51
9	.77	1.21	- 57.14	.22	.21	4.55	5.67	4.23	25.40
10	.81	1.16	- 43.21	.26	.33	- 26.92	4.76	4.47	6.09
11	2.45	2.67	- 8.98	.29	.31	- 6.90	.61		
12	3.39	3.06	9.73	1.16	1.03	11.21	.75	.33	56.00
13	5.42	5.59	- 3.14	.62	.64	- 3.23	.05		
14	4.12	4.56	- 10.68	.82	.79	3.66	3.06	1.62	47.06
15	4.17	3.98	4.56	.86	.19	77.91	1.26	1.33	- 5.56
16	2.25	2.99	- 32.89	.31	.35	- 12.90	2.94	2.57	12.59
17	3.47	4.87	- 40.35	.56	.21	62.50	1.12	2.93	-161.61
18	2.70	3.71	- 37.41	2.63	.81	69.20	1.77	14.10	-696.61
19	1.33	1.20	9.77	1.05	.29	72.38	6.96	9.85	- 41.52

TABLE 8. PERCENT VSS OF SS-FLOCCULATION/SEDIMENTATION SYSTEM

Storm No.	Inf. SS	Inf. VSS	Inf. % Vol.	Eff. SS	EFF. VSS	Eff. % Vol.
1	132.29	24.98	18.88	236.16	32.00	13.55
2						
3	137.72	58.98	42.83	122.49	48.43	39.54
4	164.65	92.09	55.93	194.13	75.11	38.69
5	71.13	31.44	44.20	93.98	82.41	87.69
6	87.75	49.84	56.80	123.36	47.34	38.38
7A	262.38	158.19	60.29	223.14	87.59	39.25
7B	74.42	46.44	62.40	50.33	15.89	31.57
8	189.12	105.67	55.87	197.30	57.51	29.15
9	302.58	158.54	52.40	180.10	80.53	44.71
10	190.48	83.65	43.92	229.44	86.46	37.68
11	171.45	85.84	50.10	120.88	57.99	47.97
12	266.01	146.04	54.90	112.06	54.40	48.55
13	195.49	132.12	67.58	119.97	70.08	58.41
14	330.72	133.59	40.39	199.71	67.89	33.99
15	449.56	162.15	36.07	34.67	6.65	19.18
16	445.37	155.25	34.86	74.50	26.64	35.76
17	162.52	79.20	48.73	50.98	17.60	34.52
18	151.82	74.12	48.82	55.60	13.40	24.10
19	183.59	41.05	22.36	59.21	17.55	29.64

SECTION 7

SWIRL CONCENTRATORS

BACKGROUND

The swirl concentrator has been developed following demonstration of a vortex regulator by Smisson (15) who noted that the device permitted solids separation in addition to functioning as an overflow regulator. Swirl concentrators achieve removals of suspended solids by rotationally induced forces causing inertial separation in addition to vertical gravity sedimentation during relatively short detention times. Originally developed as a CSO regulator (16, 17) the concept has been refined and extended to selective grit removal (18) and attainment of primary removal efficiencies (12).

Mathematical and hydraulic modeling have been conducted in the studies cited above. These models were developed using synthetic materials simulating the particle size distributions and specific gravities of grit and organics found in domestic sewage and CSO. The models are also being verified by testing in prototype and pilot facilities using actual sanitary wastewater and CSO at Lancaster, PA.(U.S. EPA Grant No. S-802219), Denver, CO. (64), Toronto, Ont. (12), and Syracuse, NY (22). Original development work (12, 16, 17, 18) has presented a series of design curves relating anticipated performance to design capacity and other design parameters.

Structurally, swirl regulators/concentrators, swirl degritters, and swirl primary separators incorporate distinctly different features. Some of these differences are illustrated on Figures 19, 20 and 21. The selected configuration for each application is a result of consideration of hydraulic principles and testing on a variety of physical models. Distinct differences are noted in weir configurations, baffling and floor layouts. The units also differ in design features such as inlet velocities, D_2/D_1 (unit diameter/inlet dimension) ratios, and H_1/D_1 (weir height/inlet dimension) ratios. The swirl regulator and degritter studies have presented results for units with D_2/D_1 ratios of 6, 7.2, 9 and 12. The swirl primary separator study employed a unit with D_2/D_1 ratio of approximately 15.

Performance results in each of the above studies were scaled from model results to predicted prototype results by using Froude Law scaling relationships. Model to prototype conversion used the Froude number

$$N_F = \frac{v^2}{gs}$$

for scaling of unit dimensions, where N_F = Froude number, v = velocity,

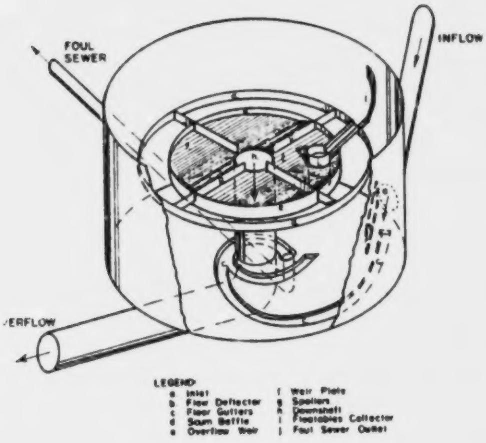

FOUL SEWER
INFLOW
ERFLOW
LEGEND
a Inlet
b Flow Deflector
c Floor Gutters
d Scum Baffle
e Overflow Weir
f Weir Plate
g Spoilers
h Downshaft
i Floatables Collector
j Foul Sewer Outlet

FIGURE 19. Swirl Regulator/ Concentrator

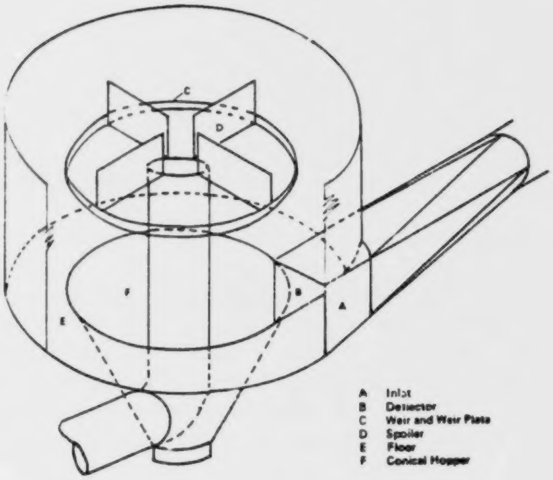

C
D
F
B
A
E
A Inlet
B Deflector
C Weir and Weir Plate
D Spoiler
E Floor
F Conical Hopper

FIGURE 20. Swirl Degritter

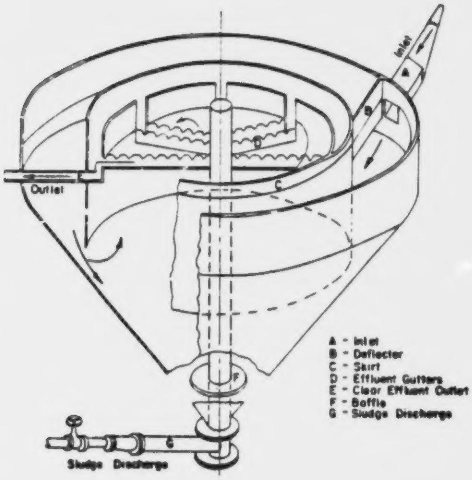

Inlet
A
B
D
C
Outlet
F
G
Sludge Discharge
A - Inlet
B - Deflector
C - Skirt
D - Effluent Gutters
E - Clear Effluent Outlet
F - Baffle
G - Sludge Discharge

FIGURE 21. Swirl Primary Separator

g = acceleration due to gravity and s = reference length.

Since v = Q/A and area, A, is a function of the square of the inlet diameter D_1

therefore, $N_F = [\frac{Q^2}{D_1{}^5}]$

Froude number scaling thus employs the relationship:

$$\frac{Q \text{ model}}{Q \text{ prototype}} = [\frac{D_1 \text{ model}}{D_1 \text{ prototype}}]^{5/2}$$

for scaling of hydraulic flows. Geometric similarity must be maintained between model and prototype. In addition, foul fraction (percent of flow which is wasted) must be the same in prototype as in the model.

In a similar manner, particle settling velocities were also scaled in the above studies using Froude Law relationships. Since

$$N_F = f\left(\frac{v^2}{s}\right)$$

scaling of settling velocities employs the relationship

$$\frac{v^2 \text{ prototype}}{v^2 \text{ model}} = \frac{D_2 \text{ prototype}}{D_2 \text{ model}} = \lambda$$

where λ = scale factor.

Since settling velocity is dependent on particle diameter and specific gravity, the above studies employed synthetic materials to represent settling velocities in the model studies. These represented scaled-down settling velocities from prototype scale for expected particle size distributions and specific gravities. The regulator studies used gilsonite and polythene, the degritter studies used sand, gilsonite and pumice, and the primary separator studies used petrothene and IRA-93 anion exchange resin to simulate, respectively, solids in CSO, grit in domestic sewage, and organics in domestic sewage.

The swirl regulator and the degritter studies reported effects of varying the H_1/D_1 ratio. Although results showed some impact on the performance within the range tested, the effect was minor in comparison to other design parameters. Selection of other unit dimensions is in conformity with maintaining geometric similarity between model and prototype.

The early work of Smisson on regulators/concentrators employed foul fractions of 30 percent using a vortex device. Later studies (12, 16, 17, 18) demonstrated removals using foul fractions in the range of 2 to 3 percent. The regulator study (16) presented results indicating that removal efficiency improved as foul fraction was increased from 3 to 30 percent. Foul fractions employed in the Rochester work are discussed in the subsections below.

OUTLINE OF EXPERIMENTS

Testing of the swirl degritter and primary separator was directed toward evaluating the effects of hydraulic loading and variable influent quality on removal efficiencies when treating Rochester CSO.

A matrix of tests was established whereby the swirl degritter and primary separator units were evaluated at five flowrates from 0.95 to 4.4 l/s (15 to 70 gpm) without chemical treatment. Flowrate was held constant throughout the duration of each storm to observe the system efficiency under variable influent solids concentrations.

Several of these tests were repeated in the program employing chemical treatments (polymer alone and alum plus polymer with and without phosphorous spiking). Selection of chemicals and dosages is described in Section 5.

Table 9 lists the matrix of tests conducted for the swirl degritter and primary separator units. Also shown on this Table is the foul percentage employed during each test. Grit withdrawal from the swirl degritter was conducted intermittently at 20 minute intervals. Sludge withdrawal for the swirl primary separator was carried out on both an intermittent and continuous basis. For intermittent withdrawal, the sludge was extracted at 20 minute intervals. Continuous sludge withdrawal was conducted utilizing hydraulic pressure differentials which forced the sludge through a 2.54 cm (1 in) line at rates ranging up to 0.3 l/s (5 gpm).

TABLE 9. SWIRL DEGRITTER AND PRIMARY SEPARATOR TEST MATRIX

Storm No.	Flowrate (gpm)	Foul Percentage Degritter	 P/S*	P/S* Chemical Addition P (mg/l)	 Alum (mg/l)	 Polymer (mg/l)
1	30					
2	30					
3	40					
4	50	0.26	0.53			
5	30	0.46	0.92			
6	30	0.44	0.88			
7A	30	0.33	0.67			
7B	50	0.26	0.53			
8	30	0.47	0.87			1.0
9	50	0.30	0.44			1.0
10	50	0.39	0.48			1.0
11	40	0.58	0.63		40	1.0
12	50	0.52	0.46		40	1.0
13	30	0.73	0.90	1.55	105	1.0
14	50	0.72	0.52			
15	40	1.12	1.26	1.37	105	1.0

(continued)

TABLE 9. (continued)

Storm No.	Flowrate (gpm)	Foul Percentage		P/S Chemical Addition		
		Degritter	P/S*	P (mg/l)	Alum (mg/l)	Polymer (mg/l)
16	50	0.22	2.4**	1.37	105	1.0
17	70	0.34	2.7**			
18	15	0.43	9.6**			
19	50				40	1.0

* P/S - Swirl primary separator ** - Sludge continuously drawn

Scaling of hydraulic flows from model to prototype uses Froude Law relationships as discussed earlier. The inlet pipe diameters, (D_1), for the degritter and primary separator swirl units were 15 and 10 cm. (6 and 4 in), respectively. The unit diameters, (D_2), were 0.91 and 1.83 m (3 and 6 ft), respectively. Thus the D_2/D_1 ratios employed in these designs were 6 and 18, respectively. Table 10 shows the flowrates tested in the pilot plant and indicates the Froude number and flowrate for a 11 m (36 ft) diameter prototype unit, corresponding to each model flowrate. This Table also indicates the detention time in the model at each flowrate.

TABLE 10. SWIRL DEGRITTER AND PRIMARY SEPARATOR: MODEL AND PROTOTYPE FLOWRATES

Model Flowrate (gpm)	Model Flowrate (mgd)	D.T. in Model (min)	Influent Froude Number	Prototype Flowrate (mgd)	D.T. in Prototype (min)
Swirl Degritter					
3 ft dia model				6 ft dia prototype	
15	0.022	4.7	0.0018	0.12	7.8
30	0.043	2.4	0.0072	0.24	3.9
40	0.058	1.8	0.0128	0.33	2.8
50	0.072	1.4	0.0200	0.41	2.3
70	0.101	1.0	0.0392	0.57	1.6
Swirl Primary Separator					
6 ft dia model				36 ft dia prototype	
15	0.022	41.3	0.0137	1.9	105.3
30	0.043	20.7	0.0547	3.8	52.6
40	0.058	15.5	0.0972	5.1	39.2
50	0.072	12.4	0.1518	6.3	31.8
70	0.101	8.8	0.2977	8.9	22.5

Particle size distributions for Rochester CSO were measured for several samples following storms 14, 15 and 17. These samples included composites of influent CSO for the first and second half of each storm and full-storm composites of effluents from the swirl degritter and swirl primary systems.

Particle size distributions were determined by passing wet samples across individual screens ranging in size from 74 to 1000 microns. SS determinations were conducted before and after screening. A small sample volume was applied per surface area of screen to prevent matte formation. The sample was initially deflocculated by adding 10 mg/l of detergent. Results of the screen analysis are presented in Table 11. Results of the influent CSO analyses are plotted on Figure 22 as a log-probability plot of percent finer versus particle size. Figure 22 also shows CSO particle size distributions presented in the APWA studies (18,64)for samples from Lancaster, PA, and San Francisco, CA. It is noted the the Rochester samples exhibited size distributions slightly finer than the other locations.

TABLE 11. PARTICLE SIZE DISTRIBUTIONS*

Size Range (microns)	Storm No.	CSO 1st Half	CSO 2nd Half	Swirl Degritter Effl. Compos.	Swirl Primary Separator Effl. Compos.
>1000	14	0	54	16	0
841-1000		27	0		
595-841		1	0		
420-595		6	8		
180-420		6	10	2	0
149-180		0	8	2	22
74-149		74	18	54	8
<74		280	192	208	148
		394	290	282	178
>1000	15	0	10	0	8
841-1000		30	10		
595-841		20	10		
420-595		50	0		
180-420		10	5	20	20
149-180		30	5	16	0
74-149		60	70	40	0
<74		480	150	254	68
		680	260	330	96
>1000	17	36	0	41	0
841-1000		10	2		
595-841		20	5		
420-595		10	0		
180-420		30	14	14	4
149-180		0	2	0	8
74-149		20	15	5	4
<74		170	48	135	80
		296	86	195	96

* Results as SS (mg/l)

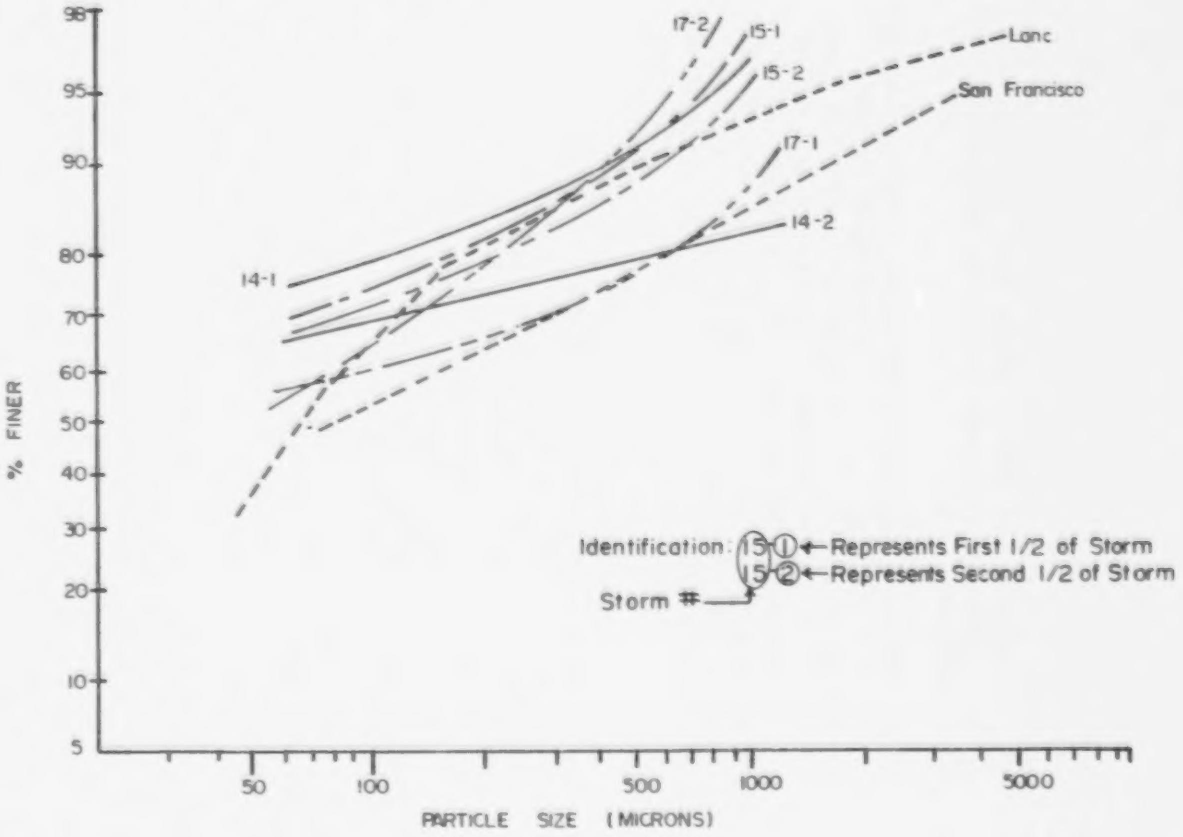


FIGURE 22. Combined Sewer Overflow Particle Size Distributions.

Specific gravity of dried sludge solids was determined following Storm No. 14 for a composite of swirl degritter and swirl primary separator sludges. The specific gravity of the combined grit and organic solids was determined as 1.70.

SWIRL DEGRITTER

Denver (64) and LaSalle (18) swirl degritter performance studies were conducted on a 1.83m (6 ft) diameter prototype unit and a 0.9m (3 ft) diameter pilot scale unit, respectively. Both studies concluded that the swirl degritter could be effectively used to remove grit solids from all wastewater flows at application rates higher than those employed in conventional aerated grit chambers.

The LaSalle study (18) was conducted to determine a design procedure for the removal of grit solids using the swirl concentrator concept. The pilot scale model consisted of a 0.9m (36 in) diameter separation chamber with a height of 1.02m (40 in). The influent pipe diameter was varied to test the model at different operating conditions. Simulated materials such as Gilsonite, pumice and fine sand were used to simulate grit material found in combined sewage. The model was scaled up to a prototype unit by using Froude Law relationships for both mass flow and particle settling velocity.

The Denver (64) study was essentially an extension of the LaSalle study (18), but conducted on a prototype scale using real sewage. The performance of this unit was also compared to the efficiency of a conventional aerated grit chamber (AGC). The swirl degritter unit consisted of a 1.83m (6 ft) diameter separation chamber with a 30.4 cm (1 ft) diameter influent pipe. The grit was defined as that component having a diameter greater than 0.20 mm and a specific gravity greater than 2.65. Chasick samplers were installed at the influent and effluent ends of the swirl degritter to measure grit greater than 0.2 mm in size.

The LaSalle report (18) calculated the grit removal efficiencies of various grit chamber diameters at different scaled-up flowrates. This report also presented a design curve for 80 to 95 percent range of grit removal efficiencies of the swirl degritter.

In the Denver (64) study, two series of tests were conducted. In the first series, only real sewage was applied to the swirl degritter, whereas in the second series of tests, dry blasting sand, size 0.25 mm, was added to the sewage after it was pumped from the influent channel. Grit removal was measured as the weight of dry grit recovered and the weight of grit ash recovered. The percentage removal of grit ash in the swirl degritter ranged from 68 to 84 percent during the first series of tests. The grit removals in the second series of tests were higher and uniform for the lower applied flows. However, the removals at the higher flow rates (2.0 and 3.0 mgd) were erratic and at times indicated negative removals.

Grit Definition

Grit is generally defined as particles greater than or equal to 0.2 mm with a specific gravity of 2.65, thus possessing a settling velocity of 2.6 cm/sec (0.085 ft/sec) or greater. The specific gravity of CSO solids measured for Storm No. 14 was 1.70. Therefore, particles of 0.3 mm size or above would have a settling velocity of 2.6 cm/sec (0.085 ft/sec) or greater. For the particle size distributions measured during Storm numbers 14, 15 and 17, the percentage of solids with particle size greater than 0.3 mm was calculated. These are shown in Table 12.

TABLE 12. GRIT SOLIDS DISTRIBUTION

Storm	Duration	Wt. % of Particles > 0.3 mm
14	1st half	8.6
14	2nd half	22.0
15	1st half	14.7
15	2nd half	11.5
17	1st half	25.7
17	2nd half	8.1

The percentage of particles greater than 0.3 mm has been defined here as the percentage of grit in the influent CSO. It was attempted to correlate percentage of grit with the influent SS level, but no strong correlation was observed. Therefore, the arithmetic mean value of grit in the influent CSO has been used as a measure of the concentration of grit in untreated CSO.

Prototype Swirl Degritter Performance

The particle size distributions tested in the model translate to a different size distribution when scaled to prototype. Figure 23 shows the mean particle size distribution of the influent to the swirl degritter for three overflow events.

Particle settling velocities are scaled from model to prototype by multiplying by the square root of the scale factor λ. A new particle size distribution is thus obtained for the prototype by entering a chart of settling velocity versus particle size and specific gravity such as those found in the APWA reports (18, 64). The results of these calculations are presented on Table 13 for the particle size distributions measured in the Rochester work. The 1.8 m (6 ft) diameter prototype size distributions are shown on Figure 23. It is noted that the particle size distribution for the prototype swirl degritter does not differ greatly from that of the pilot scale model. Therefore, the prototype swirl degritter performance equations have been developed by assuming the same particle size distribution as was observed in the pilot scale unit.

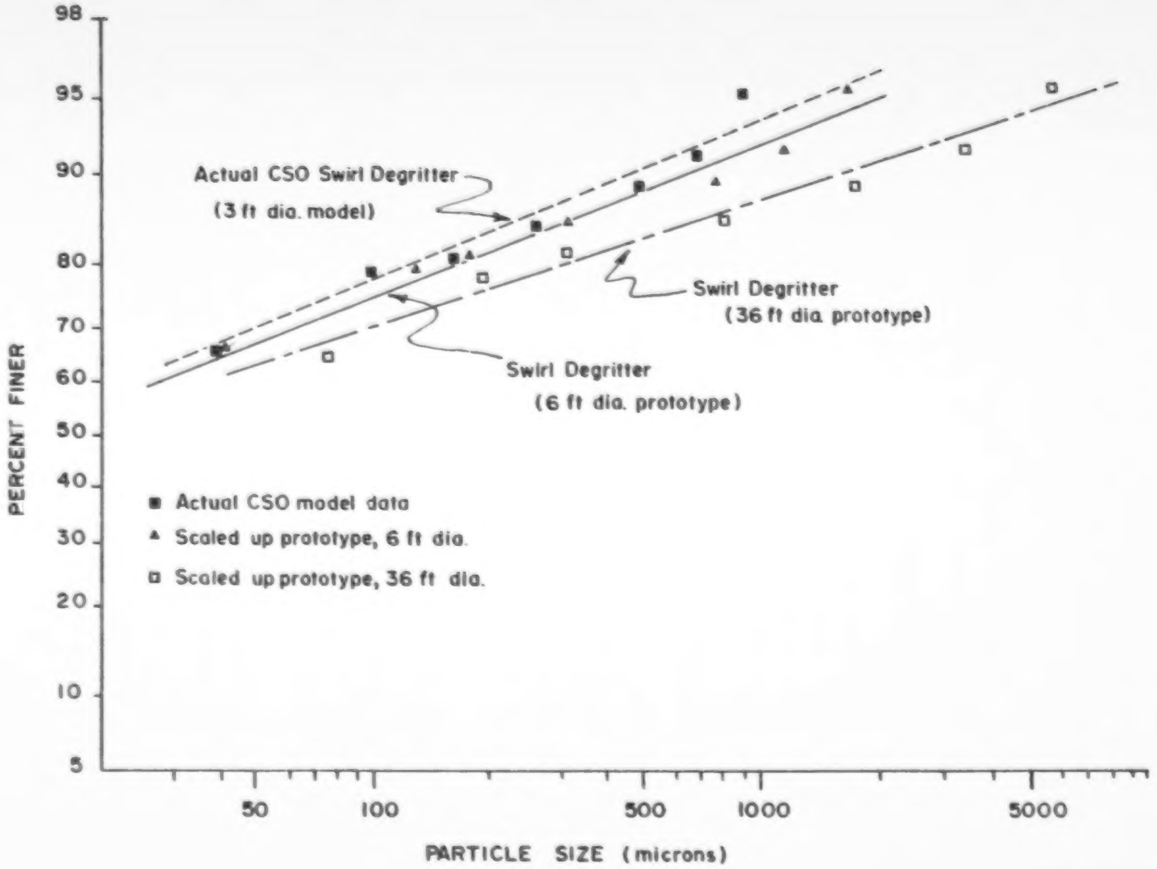


FIGURE 23. Swirl Degritter Model and Prototype Particle Size Distributions

TABLE 13. SWIRL DEGRITTER MODEL TO PROTOTYPE SCALING OF PARTICLE SIZES; S.G. = 1.70

Model Size Range (microns)	Assumed Model Size (mm)	Ave. Infl. Distrib. (%)	Settling Velocity (cm/sec) Model	Settling Velocity (cm/sec) Proto.	Prototype Size (mm)
Model dia. = 3 ft, Prototype dia. = 6 ft, $\lambda = 2$					
>1000	1.4	5.0	9.0	12.7	2.8
841-1000	0.92	3.9	7.0	9.9	1.7
595-841	0.71	2.8	5.8	8.2	1.1
420-595	0.50	3.7	4.2	5.9	0.75
180-420	0.27	3.7	2.0	2.8	0.31
149-180	0.16	2.2	0.8	1.1	0.18
74-149	0.10	12.8	0.4	0.6	0.13
<74	0.04	65.8	0.07	0.1	0.04

Results and Performance

In the Rochester CSO analysis, it has been assumed that changes in particle settling velocity distributions are reflected in the influent grit solids concentration. That is, conditions such as high sewer velocities which tend to scour heavier particles also result in higher influent grit solids concentrations. Performance of the degritting unit was thus related to influent grit solids concentration levels and the flow through the swirl degritter. Influent and effluent SS results across the swirl degritter are plotted in Appendix A. The pilot scale model was scaled from a 0.91 m (3 ft) diameter unit to a 1.83 m (6 ft) diameter unit to compare performance with the data obtained from the LaSalle and Denver studies.

Multiple regression analysis was conducted to statistically fit an equation to the pilot plant data. The following equation was obtained from the analysis:

$$g_e/g_o = k_1 + K_2 \text{ Log } Q + K_3 \text{ Log } c_o$$

where g_e/g_o = Fraction of grit remaining
Q = Flow through the swirl degritter (gpm)
c_o = Influent suspended solids concentration in the unit (mg/l)
K_1, K_2, K_3= Regression coefficients

It was assumed that grit loading to the unit varied with the measured influent SS concentration and that grit solids represented approximately 15 percent of the influent SS concentration (Table 12).

The developed regression coefficients of flow and influent SS indicated that the performance decreases with increase in flow through the swirl degritter and increases with increasing concentration of SS. The results obtained from the above regression analysis are shown in Table 14. The 'T' Values associated with the flow and influent SS represent degrees of confidence above 70 percent and 99 percent, respectively. The 'F' value gives an indication of the statistical significance of the regression expression. In the above analysis, the 'F' value represents a degree of confidence greater than 99 percent. The final regression equation obtained for the 3 ft diameter pilot system is as follows:

$$g_e/g_o = 1.36 + 0.217 \log Q - 0.653 \log c_o$$

Results of the regression analysis are indicated on Figure 24 after scaling flowrates to a 1.8 m (6 ft) diameter prototype. Figure 24 indicates that performance is affected not only by hydraulic loading but also by influent grit concentrations. The dotted line on Figure 24 indicates anticipated grit removals for the median concentration of solids in CSO at the Rochester pilot plant location.

TABLE 14. REGRESSION ANALYSIS OF PILOT PLANT SWIRL DEGRITTER DATA

Variable	Mean	Standard Deviation	Correlation X vs Y	Regression Coefficient	Std. Error of Reg. Coef.	Computed T Value
Log Q	1.57	.161	.142	.217	.198	1.09
Log c_o	2.28	.261	-.400	-.653	.122	-5.32
Dependent						
g_e/g_o	.215	.440				
Intercept			1.36			
Multiple Correlation			.408			
Std. Error of Estimate			.404			

Analysis of Variance for the Regression

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F Value
Attributable to Regression	2	5.26	2.63	16.1
Deviation from Regression	161	26.3	.163	
Total	163	31.5		

Study Comparisons

Figure 24 indicates results of the swirl degritter studies at LaSalle and Denver, both for a 1.8 m (6 ft) diameter unit. The LaSalle design curve is based on hydraulic modeling using sand, gilsonite and pumice. The Denver results express removals for grit in domestic sewage and also include some tests with sand added to domestic sewage. It is noted that the Denver data indicate grit removals significantly lower than removals predicted by the LaSalle modeling. The Rochester CSO data illustrate a trend

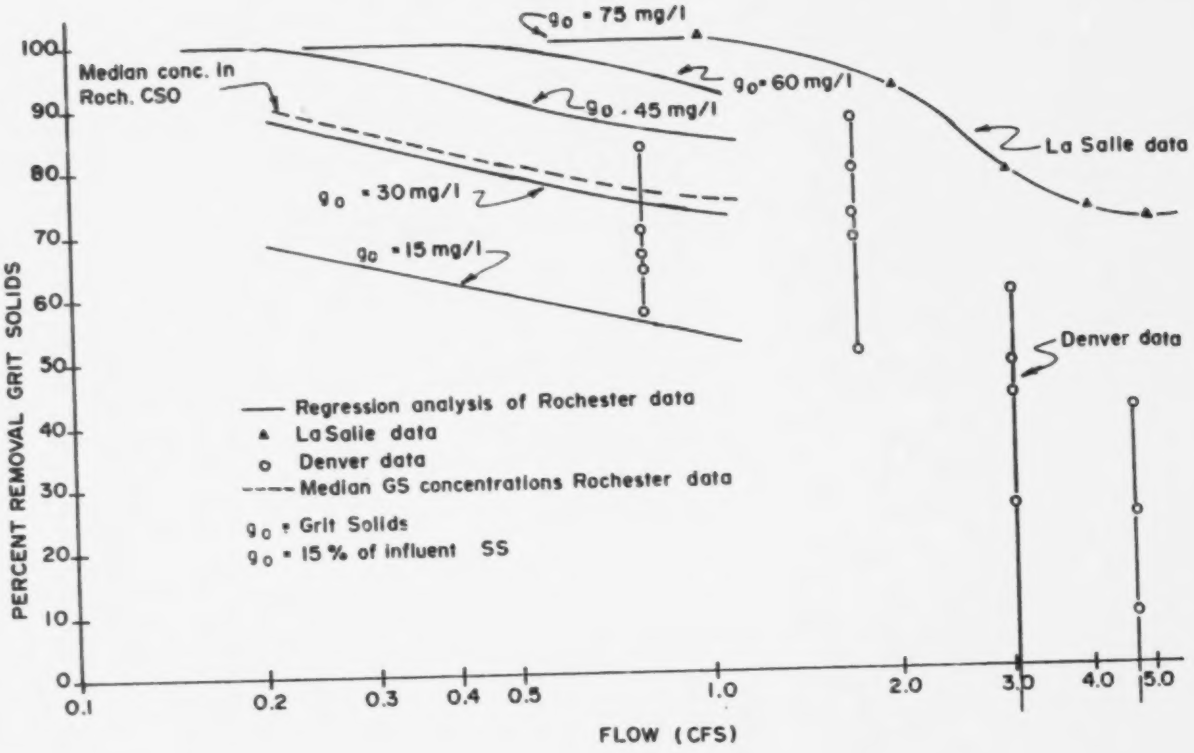


FIGURE 24. Performance of Swirl Degritter (6 ft dia. unit)

more consistent with the Denver data than that indicated by the LaSalle model.

SWIRL PRIMARY SEPARATOR

Primary treatment of CSO and municipal wastewater by the swirl primary separator principle was developed in a series of hydraulic (using synthetic sewage) and mathematical model studies (12). The developed design configuration was then tested on a pilot installation in Toronto, Canada. The purpose of the Toronto study was to verify the design when treating municipal wastewater.

The hydraulic and mathematical model studies developed a series of design curves for different size units. This study was conducted on a 0.9m (3 ft) diameter unit and was scaled to prototype sizes using Froude Law relationships. The Toronto pilot study was conducted on a 3.7 m (12 ft) diameter unit. The Toronto tests were carried out at flow rates of 1,137 m^3/day (0.3 mgd) and 1,700 m^3/day (0.45 mgd). Figure 26 shows a comparison of the predicted performance by the LaSalle design curves and the arithmetic mean of the SS removal results obtained at Toronto.

Pilot Plant Results

Data from operation of the 1.8 m (6 ft) diameter swirl primary separator at Rochester are indicated in Appendix A. These curves represent analyses corresponding to actual sampling times. Removal rates were calculated after lagging the effluent analyses by the theoretical detention time in the unit. Hydraulic loading to the unit was held constant for each storm. For each storm it was noted that SS removal rates fluctuated as a function of the influent SS concentration (c_o). It was furthermore noted that an approximately straight line relationship was developed for each storm when log (c_e/c_o) was plotted versus log c_o. Since the suspended solids concentration in CSO fluctuates in response to scouring velocities in the sewer line, c_o was viewed as a gross indicator of the particle settling velocity distribution. Thus, wastewaters during the first-flush, when c_o is highest, tend to have a greater proportion of solids of larger size and specific gravity.

The SS removal rate is also a function of hydraulic loading to the unit. In order to account for both influences, the pilot plant data were statistically fit using a multiple regression analysis to an equation of the form:

$$\log (c_e/c_o) = K_1 + K_2 \log Q + K_3 \log c_o$$

where Q = hydraulic flow applied to the unit and K_1, K_2 and K_3 are regression coefficients.

Results of the regression analysis are shown on Table 15. The signs associated with the regression coefficients indicate that SS removals generally increased with an increase in c_o and a decrease in Q. 'T' values associated with Q and c_o indicated degrees of confidence of >99 percent for the overall expression.

TABLE 15. REGRESSION ANALYSIS OF PILOT PLANT SWIRL PRIMARY SEPARATOR DATA

Variable	Mean	Standard Deviation	Correlation X vs Y	Regression Coefficient	Std. Error of Reg. Coef.	Computed T Value
Log Q	1.52	.236	.351	.447	.129	3.46
Log c_o	2.17	.279	-.215	-.239	.109	-2.18
Dependent						
Log c_e/c_o	-2.46	.297				

Intercept	-.409
Multiple Correlation	.416
Std. Error of Estimate	.273

Analysis of Variance for the Regression

Souce of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F Value
Attributable to Regression	2	1.22	.613	8.20
Deviation from Regression	78	5.83	.074	
Total	80	7.06		

The final regression equation was thus obtained as

$$c_e/c_o = 0.389\ Q^{.447}\ c_o^{-0.239}$$

The trends indicated by the regression equation are shown on Figure 25. Using this model it is possible to predict the performance of the swirl primary separator for simultaneously varying flows and influent quality such as that which occurs during an overflow event. It should be emphasized that the above equation was developed for a 0.9 m (3 ft) diameter model tested up to the flowrate of 4.4 l/s (70 gpm) and influent SS concentrations range of 100 to 800 mg/l.

On Figure 26 the Rochester regression model is compared to performance predicted by the LaSalle design curves. It is noted that for a range of c_o between 100 to 500 mg/l, the Rochester data generally support the LaSalle curve, except at the lower flowrates. It is recognized, however, that the LaSalle curves were developed for a material synthesizing the settling velocity distribution of municipal sewage while the Rochester work used actual CSO. Figure 26 also shows a comparison of results of the Toronto study (12) with the design predictions from the LaSalle study (12).

All of the analyses above used only the data from runs in which no chemical treatment was employed. In general, it was observed that chemical treatments (anionic polymer alone or alum plus anionic polymer) produced no significant improvement beyond that observed without chemicals. It is speculated that the mode of chemical addition was responsible for the lack of improvement. Because of inadequate velocity gradients and/or contact time, in-line mixing of chemicals may not have provided efficient floc development. It cannot be stated that the swirl primary separator is ineffective for separation of chemical floc.

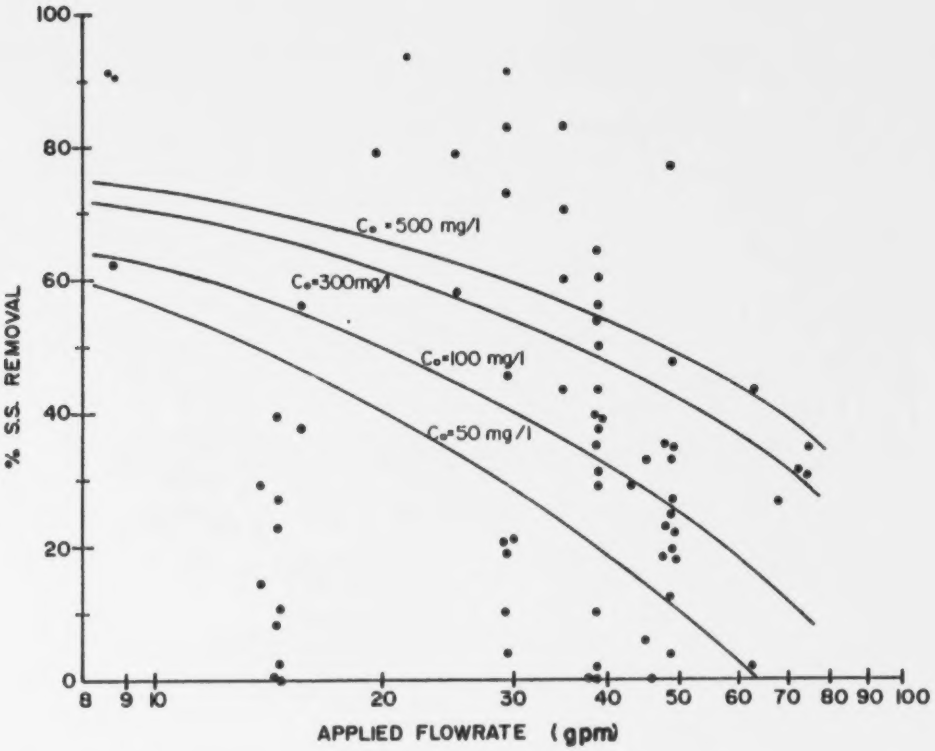


FIGURE 25. Swirl Primary Separator Regression Model and Performance Data

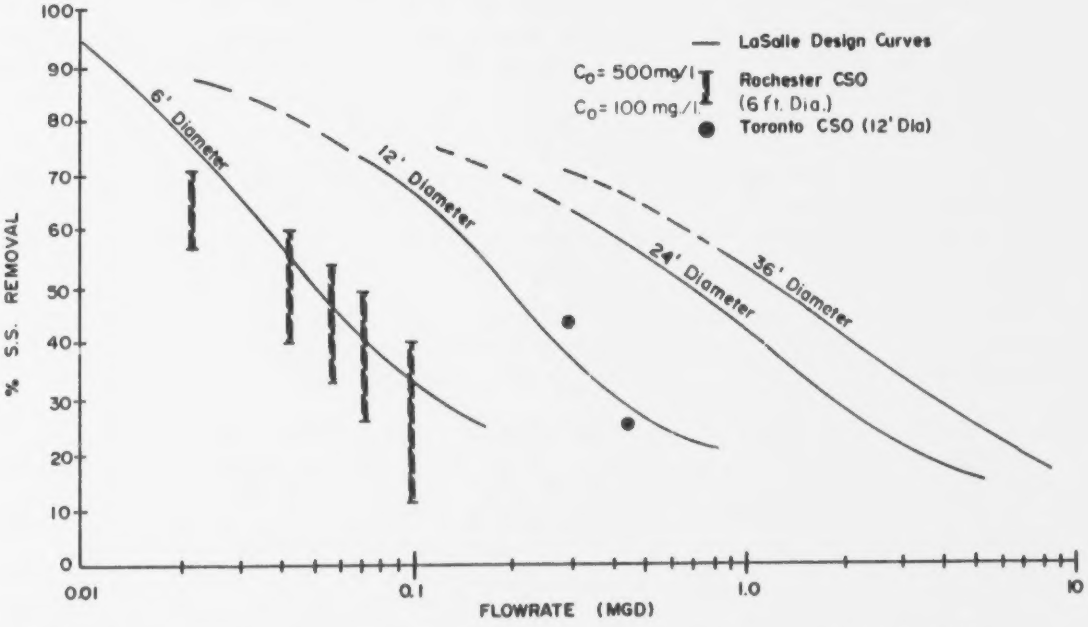


FIGURE 26. Swirl Primary Separator Loading-Performance Relationship

Scale-Up Considerations

Figure 26 illustrates the trend attained by scaling of flows and particle settling velocities as proposed by the LaSalle work. It is noted that scaling of particle settling velocities results in lower removal efficiencies for larger size prototypes at equivalent scaled hydraulic loads.

It is noted that scale-up by Froude Law results in a prototype size significantly different from that which would be obtained by traditional scale-up using OR. A rationale for the use of Froude Law scaling may perhaps be seen in data presented by Camp (7, 47) for narrow and wide rectangular sedimentation basins and circular, radial-flow basins. In evaluating the results of dye tracer studies, Camp showed that the degree of short-circuitng in the basin was related to the Froude number of the horizontal flow through the basin. Thus, by scaling based on Froude Law relationships it would be expected that the model and prototype would both display the same degree of short-circuiting.

When dealing with primary separators in which flocculent particles are removed, it may not be entirely appropriate to apply Froude Law scaling to particle settling velocities. It was noted on Table 10 that Froude Law scaling of hydraulic flows results in greater detention times in the prototype than in the model. While separation of discrete particles is theoretically independent of detention time, there are aspects of flocculent agglomeration that are affected by detention time. As flocculent particles collide, the combined particle size is increased and the settling velocity increases. This flocculation process is affected by detention time, differences in particle settling velocities, and velocity gradients in the liquid. Thus, it is possible that the loss in removal efficiency predicted by particle scaling is partially offset by increased flocculation in the larger prototype units.

Figure 27 shows the mean particle size distribution of the influent SS to the swirl primary separator for three overflow events. For scale up from model to prototype, particle settling velocities have been scaled by multiplying by the square root of the scale factor λ. Table 16 presents the prototype particle size distributions for the data obtained in Rochester.

TABLE 16. SWIRL PRIMARY SEPARATOR-MODEL TO PROTOTYPE SCALING OF PARTICLE SIZES, S.G. = 1.70

Model Size Range (microns)	Assumed Model Size (mm)	Ave. Infl. Distrib. (%)	Settling Velocity (cm/sec) Model	Settling Velocity (cm/sec) Proto.	Prototype Size (mm)
Model dia. = 6 ft, prototype dia. = 36 ft; λ = 6					
1000	0.60	7.1	5.1	12.5	2.5
180-420	0.27	4.5	2.0	4.9	0.55
149-180	0.16	2.2	0.8	2.0	0.26
74-149	0.10	12.3	0.4	1.0	0.17
<74	0.04	73.9	0.07	0.17	0.065

Figure 27 shows the particle size distributions for the 1.83 m (6 ft) diameter pilot scale model and the 11.0 m (36 ft) diameter prototype unit. If Froude Law scaling of particle settling velocities is to be employed, it may be necessary to adjust removal rates to account for the coarser size distribution represented in the prototype. However, as discussed above, this may be offset by the longer detention times in the prototype.

REMOVALS OF OTHER CONSTITUENTS

Removals of pollutants other than SS were evaluated on a storm-average basis. Listings of minimum, maximum, arithmetic means, geometric means, and standard deviations of influent and effluent data are included in Appendix C. For each of the parameters the geometric mean or median data were compiled for each storm and median removal rates were determined (see Tables 17 and 18).

Tables 19 and 20 show the percent VSS of SS for the influent and effluent samples for the swirl degritter and the swirl primary separator systems. Mean percent VSS of SS in the raw CSO for all storms was 48.6 percent.

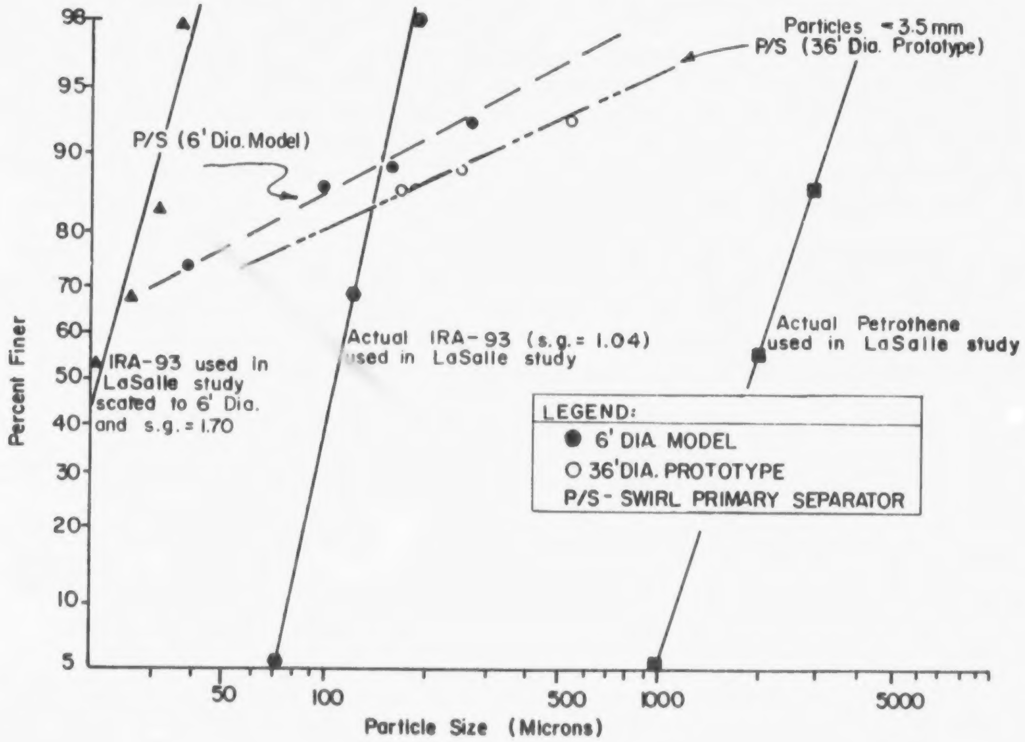


FIGURE 27. Swirl Primary Separator Model and Prototype Particle Size Distributions (specific gravity = 1.70).

TABLE 17. SWIRL DEGRITTER SYSTEM

Storm No.	SS Data (mg/l) Median Infl.	Median Effl.	% Removal	VSS Data (mg/l) Median Infl.	Median Effl.	% Removal	SETTS Data (mg/l) Median Infl.	Median Effl.	% Removal	BOD5 Data (mg/l) Median Infl.	Median Effl.	% Removal
1	132.29	134.58	-1.73	24.98	24.39	2.36				7.82	10.35	-32.35
2												
3	137.72	112.27	18.48	58.98	50.14	14.99	2.64	1.94	26.52	29.63	32.75	-10.53
4	164.65	124.05	24.66	92.09	64.08	30.42						
5	71.13	124.84	-75.51	31.44	112.96	-259.29				340.97	1302.0	-281.85
6	87.75	139.23	-58.67	49.84	74.20	-48.88	1.83	1.54	15.85	20.58	13.16	36.05
7A	262.38	245.31	6.51	158.19	120.32	23.94	5.36	5.66	-5.60	82.47	75.09	8.95
7B	74.42	41.38	44.40	46.44	14.38	69.04	.41	0.36	12.20	21.74	15.79	27.37
8	189.12	249.75	-32.06	105.67	75.14	28.89	2.13	2.72	-27.70	71.46	72.02	-0.78
9	302.58	184.56	39.00	158.54	84.74	46.55	1.71	1.23	28.07	30.18	20.74	31.28
10	190.48	259.85	-36.42	83.65	102.34	-22.34	1.24	0.88	29.03	51.32	32.98	35.74
11	171.35	149.35	12.84	85.84	76.99	10.31	1.55	1.37	11.61	37.27	36.05	3.27
12	266.01	164.06	38.33	146.04	42.56	70.86	2.52	2.09	17.06	77.82	45.72	41.25
13	195.49	249.69	-27.73	132.12	116.44	11.87	4.00	3.69	7.75	102.25	54.59	46.61
14	330.72	336.95	-1.88	133.59	143.41	-7.35	6.73	6.22	7.58	135.12	97.08	28.15
15	449.56	302.16	32.79	162.15	97.07	40.14	7.10	11.00	-54.93	121.37	60.95	49.78
16	445.37	239.85	46.15	155.25	62.60	59.68	1.40	6.60	-371.43	48.71	25.68	47.28
17	162.52	148.09	8.88	79.20	101.54	-28.21	8.45	7.40	12.43	126.26	113.28	10.28
18	151.82	109.29	28.01	74.12	46.76	36.91	5.88	2.66	54.76	71.43	56.46	20.96
19	182.59			41.05			2.24			35.58		

(continued)

TABLE 17. (continued)

	COD Data (mg/l)			TOC Data (mg/l)			O&G Data (mg/l)			pH Data	
Storm No.	Median Infl.	Median Effl.	% Removal	Median Infl.	Median Effl.	% Removal	Median Infl.	Median Effl.	% Removal	Median Infl.	Median Effl.
1	7.93	5.48	30.90	16.87	18.62	- 10.37	9.34	12.50	- 33.83	6.18	6.03
2	28.23	21.13	21.61	48.22	44.98	6.72	28.92	29.06	- .48	5.72	5.78
3	97.00			20.45	17.90	12.47	24.19	24.82	- 2.60	5.90	5.92
4											
5		41.00		109.67	82.21	25.04	20.36			6.21	
6	25.41	26.18	- 3.03	30.65	34.04	- 11.42	1.27			6.80	
7A	54.04	51.01	5.61	61.66	52.44	14.95		31.00		7.07	
7B	25.42	21.34	16.05	14.15	13.38	5.44		7.00		7.02	
8	86.49			48.31	51.74	- 7.10		28.00		6.51	7.81
9	11.04	18.15	- 64.40	31.39	31.89	- 1.59		20.00		7.17	7.33
10	15.69	15.48	1.34	44.01	30.33	31.08		42.00		7.16	7.65
11				26.27	26.28	- .04		24.00		8.09	
12				30.59	31.34	- 2.45		18.50		6.68	
13				60.46	63.52	- 5.06	64.17	88.00	- 37.18	7.00	
14				114.47	99.44	13.13	46.67	32.00	31.43	7.63	
15				55.94	87.45	- 56.33	41.55	56.00	- 34.78	7.20	
16				47.71	40.36	15.41	27.41	18.00	34.33	7.12	
17				67.29	67.07	.33	38.48	100.00	-159.88	6.86	
18				44.90	33.49	25.41	50.87	66.00	- 29.74	6.97	
19				19.16			54.39			7.61	

(continued)

TABLE 17. (continued)

Storm No.	TKN Data (mg/1) Median Infl.	TKN Data (mg/1) Median Effl.	TKN Data (mg/1) % Removal	TIP Data (mg/1) Median Infl.	TIP Data (mg/1) Median Effl.	TIP Data (mg/1) % Removal
1	.29	.27	6.90	.10	.08	20.00
2	2.63	2.19	16.73	.24	.25	- 4.17
3	1.10	.87	20.91	.26	.20	23.08
4						
5	6.20	4.96	20.00	1.49	1.15	22.82
6	2.50	2.33	6.80	.55	.52	5.45
7A	4.57	4.84	- 5.91	.63	.60	4.76
7B	1.22	.81	33.61	.18	.18	.00
8	3.05	.18	94.10	.42	.94	-123.81
9	.77	1.34	- 74.03	.22	.31	- 40.91
10	.81	1.21	- 49.38	.26	.17	34.62
11	2.45	2.24	8.57	.29	.26	10.34
12	3.39	2.34	30.97	1.16	.09	92.24
13	5.42	6.62	- 22.14	.62		
14	4.12	4.59	- 11.41	.82	.71	13.41
15	4.17	2.49	40.29	.86		
16	2.25	2.05	8.89	.31		
17	3.47	4.42	- 27.38	.50	.61	- 8.93
18	2.70	2.51	7.04	.50	.41	18.00
19	1.33			.20		

TABLE 18. SWIRL PRIMARY SEPARATOR SYSTEM

	SS Data (mg/l)			VSS Data (mg/l)			SETTS Data (mg/l)			BOD_5 Data (mg/l)		
Storm No.	Median Infl.	Median Effl.	% Removal	Median Infl.	Median Effl.	% Removal	Median Infl.	Median Effl.	% Removal	Median Infl.	Median Effl.	% Removal
1	134.58	122.88	8.69	24.39	53.86	-120.83				10.35		
2												
3	112.27	80.67	28.15	50.14	27.93	44.30	1.94	.76	60.82	32.75	24.63	24.79
4	124.05	56.56	54.41	64.08	12.19	80.98						
5	124.84	135.25	- 8.34	112.96	120.86	- 6.99				1302.00	1739.00	-33.56
6	139.23	35.55	74.47	74.20	20.31	72.63	1.54	1.41	8.44	13.16	14.67	- 11.47
7A	245.31	300.72	- 22.59	120.32	147.87	- 22.90	5.66	4.67	17.49	75.09	89.58	- 19.30
7B	41.38	55.69	- 34.58	14.38	23.24	- 61.61	.36	.33	8.33	15.79	18.31	- 15.96
8	249.75	198.70	20.44	75.14	63.19	15.90	2.72	1.55	43.01	72.02	64.02	11.11
9	184.56	209.35	- 13.43	84.74	87.09	- 2.77	1.23	1.07	13.01	20.74	22.87	- 10.27
10	259.85	175.81	32.34	102.34	63.54	33.03	.88	1.13	- 28.41	32.98	24.86	24.62
11	149.35	113.48	24.02	76.99	47.11	38.81	1.37	2.61	- 90.51	36.05	24.35	32.45
12	164.06	121.79	25.76	42.56	58.39	- 37.19	2.09	1.56	25.36	45.72	29.61	35.24
13	249.69	153.71	38.44	116.44	59.84	48.61	3.69	.22	94.04	54.54	39.63	27.40
14	336.95	260.12	22.80	143.41	104.00	27.48	6.22	2.62	57.88	97.08	79.07	18.55
15	302.16	109.85	63.65	97.07	32.10	66.93	11.00	1.75	84.09	60.95	31.76	47.89
16	239.85	135.90	43.34	62.60	41.81	33.21	6.60	3.77	42.88	25.68	18.19	29.17
17	148.09	121.58	17.90	101.54	79.65	21.56	7.40	4.49	39.32	113.28	110.44	2.51
18	109.29	88.32	19.19	46.76	37.15	20.55	2.66	.32	87.97	56.46	51.21	9.30
19	183.59	91.77	50.01	41.05	24.99	39.12	2.24	1.18	47.32	35.58	24.63	30.78

(continued)

TABLE 18. (continued)

	COD Data (mg/1)			TOC Data (mg/1)			O&G Data (mg/1)			pH Data	
Storm No.	Median Infl.	Median Effl.	% Removal	Median Infl.	Median Effl.	% Removal	Median Infl.	Median Effl.	% Removal	Median Infl.	Median Effl.
1	5.48	10.65	-94.34	18.62	18.08	2.90	12.50	10.38	16.96	6.03	5.90
2	22.13	22.25	-.54	44.98	42.92	4.58	29.06	33.45	-15.11	5.78	5.86
3				17.90	16.63	7.09	24.82	11.22	54.79	5.92	5.89
4											
5	41.00	39.72	3.12	82.21	73.19	10.97					
6	26.18	29.03	-10.89	34.04	33.57	1.38					
7A	51.01	61.24	-20.05	52.44	96.45	-83.92	31.00	24.00	22.58		
7B	21.34	22.02	-3.19	13.38	14.95	-11.73	7.00	14.00	-100.00		
8		83.91		51.74	50.08	3.21	28.00	15.00	46.43	7.81	7.56
9	18.15	11.31	37.69	31.89	21.22	33.46	20.00	24.00	-20.00	7.33	7.47
10	15.48	16.57	-7.04	30.33	20.96	30.89	42.00	38.00	9.52	7.65	7.85
11				26.28	25.74	2.05	24.00	16.00	33.33		
12				31.34	26.06	16.85	18.50	15.00	18.92		
13				63.52	42.34	33.34	88.00	76.00	13.64		
14				99.44	68.20	31.42	32.00	30.00	6.25		
15				87.45	33.02	62.24	56.00	17.00	69.64		
16				40.36	31.80	21.21	18.00	15.00	16.67		
17				67.07	33.91	49.44	100.00	88.00	12.00		
18				33.49	32.92	1.70	66.00	67.00	-1.52		
19				19.16	18.01	6.00	54.39	49.00	9.91	7.61	

(continued)

TABLE 18. (continued)

Storm No.	TKN Data (mg/1) Median Infl.	TKN Data (mg/1) Median Effl.	TKN Data (mg/1) % Removal	TIP Data (mg/1) Median Infl.	TIP Data (mg/1) Median Effl.	TIP Data (mg/1) % Removal	Aluminum Data (mg/1) Median Infl.	Aluminum Data (mg/1) Median Effl.	Aluminum Data (mg/1) % Removal
1	.27	.39	- 44.44	.08	.09	- 12.50			
2	2.19	2.90	- 32.42	.25	.33	- 32.00			
3	.87	1.26	- 44.83	.20	.31	- 55.00			
4									
5	4.96	4.29	13.51	1.15	1.10	4.35			
6	2.33	2.30	1.29	.52	.51	1.92			
7A	4.84	5.91	- 22.11	.60	.61	- 1.67			
7B	.81	.94	- 16.05	.18	.20	- 11.11			
8	.18	2.86	-1488.89	.94	.41	56.38			
9	1.34	1.31	2.24	.31	.10	67.74			
10	1.21	1.49	- 23.14	.17	.20	- 17.65	1.92		
11	2.24	1.58	29.46	.26	.02	92.31			
12	2.34	2.18	6.84	.09	.10	- 11.11			
13	6.62	7.40	- 11.78	1.55	2.04	- 31.61			
14	4.59	5.11	- 11.33	.71	.65	8.45			
15	2.49	2.30	7.63	1.37	1.50	- 9.49		134.00	
16	2.05	2.40	- 17.07	1.37	.68	50.36			
17	4.42	4.74	- 7.24	.61	.46	24.59			
18	2.51	2.84	- 13.15	.41	.47	- 14.63			
19	1.33	1.57	- 18.05	.20	.20	.00	6.96		

TABLE 19. SWIRL DEGRITTER - PERCENT VSS OF SS

	- - - mg/l - - -			- - - mg/l - - -		
Storm No.	Inf. SS	Inf. VSS	Inf. Vol. %	Eff. SS	Eff. VSS	Eff. Vol. %
1	132.29	24.98	18.88	134.58	24.39	18.12
2	137.72	58.98	42.83	112.27	50.14	44.66
3	164.65	92.09	55.93	124.05	64.08	51.66
4	164.65	92.09	55.93	124.05	64.08	51.66
5	71.13	31.44	44.20	124.84	112.96	90.48
6	87.75	49.84	56.80	139.23	74.20	53.29
7A	262.38	158.19	60.29	245.31	120.32	49.05
7B	74.42	46.44	62.40	41.38	14.38	34.75
8	189.12	105.67	55.87	249.75	75.14	30.09
9	302.58	158.54	52.40	184.56	84.74	45.91
10	190.48	83.65	43.92	259.85	102.34	39.38
11	171.35	85.84	50.10	149.35	76.99	51.55
12	266.01	146.04	54.90	164.06	42.56	25.94
13	195.49	132.12	67.58	249.69	116.44	46.63
14	330.72	133.59	40.39	336.95	143.41	42.56
15	449.56	162.15	36.07	302.16	97.07	32.13
16	445.37	155.25	34.86	239.85	62.60	26.10
17	162.52	79.20	48.73	148.09	101.54	68.57
18	151.82	74.12	48.82	109.29	46.76	42.79

TABLE 20. SWIRL PRIMARY SYSTEM - PERCENT VSS OF SS

	- - - mg/l - - -			- - - mg/l - - -		
Storm No.	Inf. SS	Inf. VSS	Inf. Vol. %	Eff. SS	Eff. VSS	Eff. Vol. %
1	134.58	24.39	118.12	122.88	53.86	43.83
2						
3	112.27	50.14	44.66	80.67	27.93	34.62
4	124.05	64.08	51.66	56.56	12.19	21.55
5	124.84	112.96	90.48	135.25	120.86	89.36
6	139.23	74.20	53.29	35.55	20.31	57.13
7A	245.31	120.32	49.05	300.72	147.87	49.17
7B	41.38	14.38	34.75	55.69	23.24	41.73
8	249.75	75.14	30.09	198.70	63.19	31.80
9	184.56	84.74	45.91	209.35	87.09	41.60
10	259.85	102.34	39.38	175.81	68.54	38.99
11	149.35	76.99	51.55	113.48	47.11	41.51
12	164.06	42.56	25.94	121.79	58.39	47.94
13	249.69	116.44	46.63	153.71	59.84	38.93
14	336.95	143.41	42.56	260.12	104.00	39.98
15	302.16	97.07	32.13	109.85	32.10	29.22
16	239.85	62.60	26.10	135.90	41.81	30.77
17	148.09	101.54	68.57	121.58	79.65	65.51
18	109.29	46.76	42.79	88.32	37.15	42.06
19	183.59	41.05	22.36	91.77	24.99	27.23

SECTION 8

MICROSCREENING

GENERAL

The microscreen is a liquid straining device that utilizes a micro fabric mesh to remove suspended materials from liquid-solid suspension. Although the use of the microscreen in the waste treatment field is not new, application of the units for the treatment of CSO has been very limited. Microscreen studies conducted by the Hydrotechnic Corporation (14) demonstrated suspended solids removals ranging from 17 to 40 percent and BOD_5 removals of 4 to 22 percent. The screens employed during these investigations had aperture sizes of 420 and 841 microns. NeKetin and Dennis (25), utilizing screens with a 105 micron aperture size, found suspended solids and COD removals equal to 26.6 and 15.5 percent, respectively. Microscreen experiments conducted by Glover and Herbert (26) exhibited suspended solids removals of 20 to 93 percent. The screen aperture size utilized during their investigations was 23 microns. Also, organic matter, as measured by COD and TOC, was found to be reduced by 25 to 40 percent. Glover and Herbert (26) also suggested that conventional microscreens employed in CSO treatment be operated at high headloss differentials of approximately 61 cm (24 in). They proposed that this differential would permit loading rates of 142 to 1831 l/min m^2 (35 to 45 gpm/ft^2) of screen area and produce an effluent quality of 40 mg/l suspended solids.

The microscreen used at the Rochester pilot plant was comprised of a vertically aligned cylindrical drum, the lower portion of which was covered with a woven micromesh filter fabric (See Figure 6). When in operation, the drum rotated about its vertical axis at peripheral speeds of 91 to 213 m/min (300 to 700 fpm) which corresponds to a rotational speed of 58 to 136 rpm. A sonic transducer was rigidly mounted on a stationary support inside the strainer drum and as the fabric-covered portion of the drum passed over the transducer, it was cleaned by the gas cavitation that was developed in the liquid at the surface of the drum as a result of the high-energy sound waves produced by the sonic transducer. Because the sonic transducer must be covered with liquid to effectively clean the fabric, the liquid (filtrate) inside the drum must be maintained at a level sufficient to keep the transducer submerged. The liquid outside the drum was maintained at a level greater than that of the filtrate so that a differential head was established, forcing the unfiltered liquid outside the drum through the filter fabric.

The microscreening process at the pilot plant was evaluated in comparison to swirl concentrators to establish primary solids removal prior to filtration. The purpose of this comparison was to investigate the type of pretreatment efficiency necessary (90 percent SS removal for microstraining or 50 to 70 percent SS removal for swirls) to optimize the performance of dual-media high-rate filtration.

OUTLINE OF EXPERIMENTS

Two of the more important variables that are relative to the microscreening process are hydraulic loading rates and screen aperture size. Since there are no historical data on the overall performance and efficiency of sonically-cleaned microscreens in treating combined sewer overflows, it was necessary to concentrate on hydraulic loading rates during the initial testing stages. The emphasis of operation during the initial investigations was concerned with establishing screen performance at hydraulic rates of 1000 to 1200 l/min m^2 (25 to 30 gpm/ft^2).

The microscreen was originally equipped with screens having an aperture size of 10 microns based on manufacturer's recommendation. Hydraulic loading rates greater than 400 l/min m^2 (10 gpm/ft^2) were unattainable without creating an overflow condition in the unit when using the 10 micron screens. This condition could have been due to the screen aperture size and/or to the ineffectiveness of the sonic cleaning mechanism. In an attempt to attain higher hydraulic loadings, the 10 micron screens were replaced with screens having an aperture size of 70 microns. However, subsequent testing of the microscreen, utilizing the larger aperture screens, failed to yield any improvement in performance.

Examination of the microscreen unit disclosed a faulty transducer in the sonic cleaning mechanism. The mechanism was returned to service only prior to Storm No. 13. Because of time limitations in the pilot plant program, subsequent testing of the microscreen unit was restricted to maximizing the hydraulic loading rate.

RESULTS AND PERFORMANCE

Evaluations of the microscreening process were fairly limited due to the problems encountered with the sonic cleaning mechanism. Results of the first dry weather test (Storm No. 67) conducted in the microscreen are presented in Figure 28. Suspended solids removals averaged 33 percent at a loading of 895 l/min m^2 (22 gpm/ft^2). Operating at a drum speed of 136 rpm, headloss in the unit stabilized at 30 cm (12 in).

During the next wet weather test, the microscreen unit reached a loading rate of approximately 407 l/min m^2, operating under a head differential of 25 cm (10 in). Drum speed during this investigation was maintained at 136 rpm. Figure 29 shows the suspended solids removal efficiency for this test. Mass balance calculations indicated that a very small fraction of the solids removed were present in the solids blowdown. The majority of solids accumulated upstream of the strainer.

Following the above tests, the screens were steam cleaned and a series of dry weather tests were conducted. Higher headlosses generally prevented operation beyond a hydraulic loading of 407 l/min m^2 (10 gpm/ft^2). The

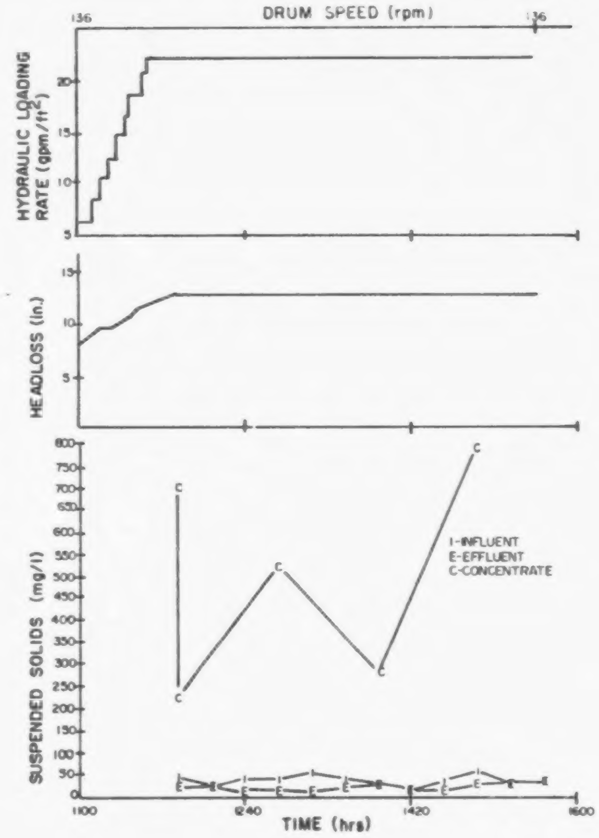


FIGURE 28. Microscreen System Performance Storm No. 67 (2/25/76) (dry-weather flow)

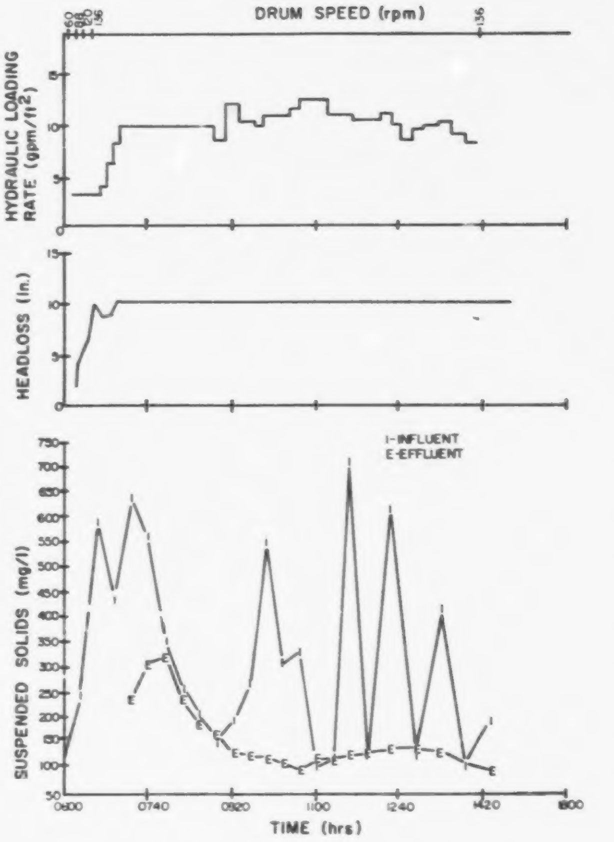


FIGURE 29. Microscreen System Performance Storm No. 12 (3/2/76) (wet-weather flow)

hydraulic loading and the drum speed were gradually increased to 407 l/min m^2 (10 gpm/ft^2) and 136 rpm, respectively. Headlosses associated with the higher loading rates were much smaller than the headlosses incurred by the sudden increase in loading rates as was done in the above tests. Figures 30 and 31 present suspended solids removal results for the two dry weather tests conducted under the above operating conditions. Figure 32 presents the SS removal efficiency of the unit at a maximum hydraulic loading of 598 l/min m^2 (14.7 gpm/ft^2) and a rotational speed of 136 rpm. The headloss incurred in this test was 44 cms (17.5 in). A final wet-weather analysis was conducted by increasing the rotational speed of the drum to 136 rpm at a hydraulic loading of 273 l/min m^2 (6.7 gpm/ft^2). Figure 33 presents the system performance results during the final wet-weather analysis.

From the above analysis, it appears that the rotational speed is a very important parameter in the operation of the unit. Results indicated that the microscreen performance improved considerably when the microscreen drum was rotated at the maximum speed. With the exception of one storm the maximum hydraulic loading attainable without producing overflow was 549 l/min m^2 (13.5 gpm/ft^2). This appeared to be the operating limit of the microscreen for both wet- and dry-weather flows at the Rochester pilot plant site. During wet-weather flows, operation of the unit was considerably more erratic and hydraulic loadings attainable were lower than those experienced during dry-weather investigations. This could have been due to the varying level of suspended solids present in the influent. Influent suspended solids averaged 240 to 317 mg/l during the wet-weather investigations and 40 to 60 mg/l during the dry-weather operations. However, the higher influent SS during wet-weather testing did not always result in higher SS removals as seen in Table 21.

A list of removal percentages for all the parameters analyzed during the microscreen investigations is presented in Table 21. A statistical analysis of this data for storm operations is presented in Appendix C.

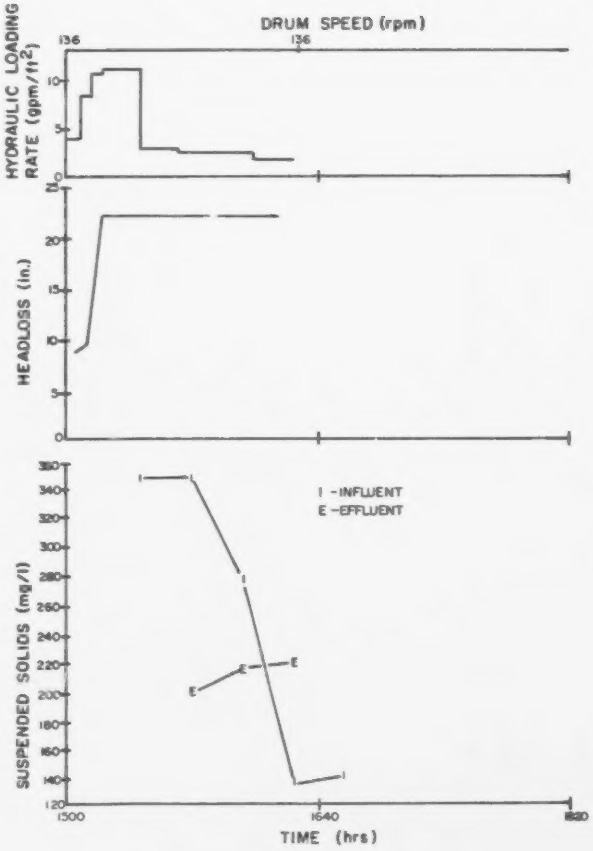


FIGURE 30. Microscreen System Performance Storm No. 13 (3/12/76) (wet-weather flow)

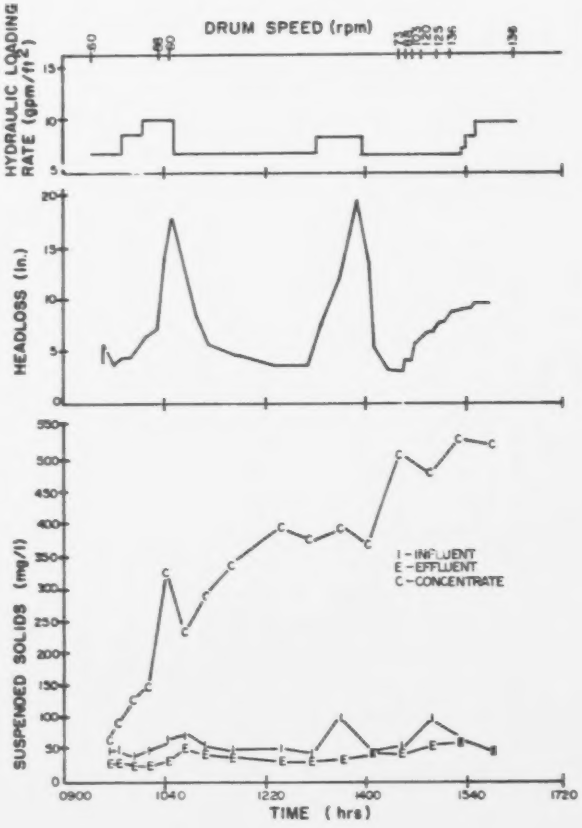


FIGURE 31. Microscreen System Performance Storm No. 71 (5/3/76) (dry-weather flow)

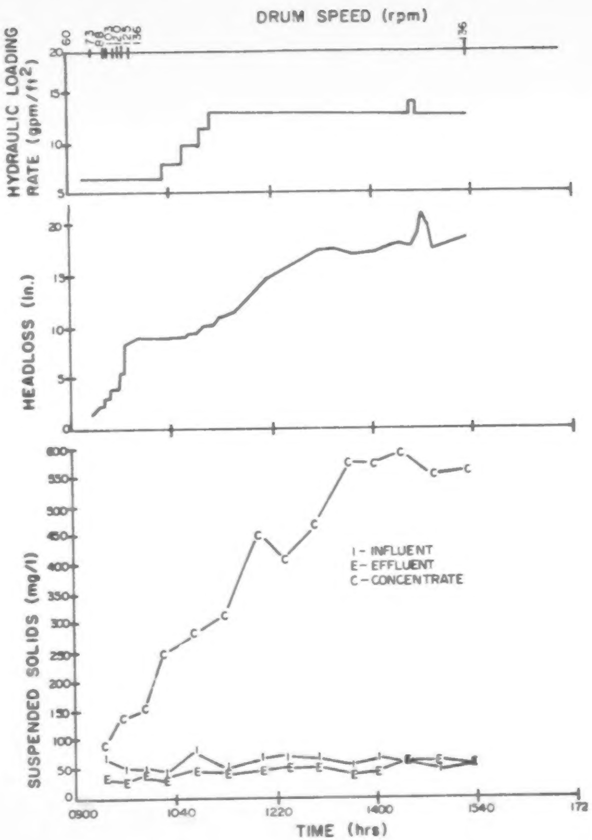


FIGURE 32. Microscreen System Performance Storm No. 72 (5/4/76) (dry-weather flow)

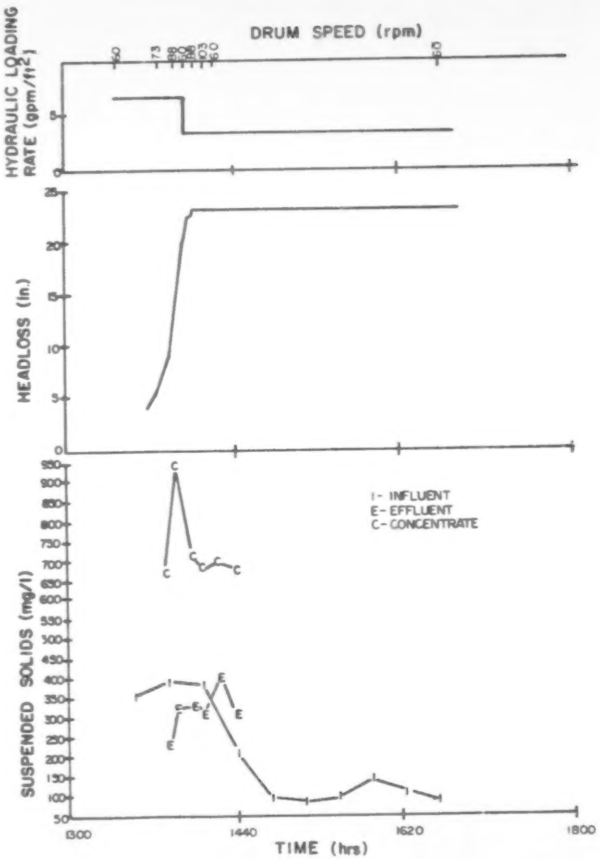


FIGURE 33. Microscreen System Performance Storm No. 17 (5/11/76) (wet-weather flow)

TABLE 21. MICROSCREENING ANALYTICAL DATA*

PARAMETER	WET WEATHER ANALYSIS			DRY WEATHER ANALYSIS		
Storm No.	12	13	17	67	71	72
Infl. SS (mg/l)	261.2	236.9	317.3	40.5	54.6	59.5
Effl. SS (mg/l)	147.6	212.1	314.5	27.3	36.7	45.6
% SS Removal	43.5	10.5	1.5	32.6	32.8	23.4
Infl. BOD_5 (mg/l)	82.6	107.9	209.6			
Effl. BOD_5 (mg/l)	42.6	109.0	201.4			
% BOD_5 Removal	48.4		3.9			
Infl. VSS (mg/l)	128.3	154.5	200.6	35.3		
Effl. VSS (mg/l)	62.3	114.0	188.4	22.8		
% VSS Removal	51.4	26.2	6.1	35.4		
Infl. SETTS (mg/l)	2.48	9.41	13.50			
Effl. SETTS (mg/l)	0.87	3.62	7.14			
% SETTS Removal	64.9	61.5	47.1			
Infl. TIP (mg/l)	7.27	0.63	1.01			
Effl. TIP (mg/l)	0.41	0.99	1.23			
% TIP Removal	94.4					
Infl. TKN (mg/l)	3.56	4.88	3.32			
Effl. TKN (mg/l)	3.42	6.49	6.74			
% TKN Removal	3.9					
Infl. TOC (mg/l)	29.6	62.9	107.4			
Effl. TOC (mg/l)	43.2	85.2	97.7			
% TOC Removal			9.0			
Infl. O & G (mg/l)		86.0	59.0			
Effl. O & G (mg/l)		76.0	52.1			
% O & G Removal		11.6	11.7			

* Results are geometric means of the values obtained

SECTION 9

DUAL-MEDIA HIGH-RATE FILTRATION

BACKGROUND

Studies of wastewater filtration have focused primarily on polishing of secondary effluents. In this application deep bed filters have been employed at hydraulic loading rates of 81 to 407 l/min m^2 (2 to 10 gpm/ft^2). Dual or multi-media filters are generally preferred in wastewater applications, as they allow more efficient use of the filter depth.

In addition to removal efficiencies, the performance of filter units is characterized by the run lengths attainable as determined by the rate of headloss. Since run length is also affected by the hydraulic loading rate, a more appropriate measure of production is specific capture or the total kilograms of SS accumulated per m^2 of surface area per run.

When treating secondary effluent, Baumann and Huang (31) have indicated results showing up to 85 percent removal of SS when employing 30 cm (12 in) of 1.84 mm anthracite over 30 cm (12 in) of 0.55 mm sand. Specific captures of 3 to 3.6 kg/m^2 (0.62 to 0.73 lb/ft^2) per run were demonstrated when employing terminal headlosses of 3 m (10 ft) of water. Their work indicated that specific capture was basically unaffected by hydraulic loading and applied solids concentration, but was related mainly to filter media size. Tchobanoglous and Eliassen (32) developed a mathematical model for determining specific capture based on data for activated sludge effluent from Palo Alto, Cal. They indicated specific captures ranging from 1.95 to 12.7 kg/m^2 (0.4 to 2.6 lb/ft^2) per run as media size was increased from 0.4 to 1.5 mm diameter.

The filter performance equations employed in the EPA SWMM II model (34) are based partly on secondary effluent filtration studies at Chicago reported by Lynam et al. (33). These studies demonstrated SS removals of 65 to 78 percent for 0.58 mm sand with hydraulic loading (flux) rates of 102 to 244 l/min m^2 (2.5 to 6 gpm/ft^2). The filter results obtained at Washington, D.C. (35) using a synthetic storm overflow were also incorporated in the SWMM model. This report presented results for three filters. The first filter consisted of fiberglass media which demonstrated SS removals of 87 to 95 percent and BOD_5 removals of 60 to 75 percent for flux rates of 610 to 2035 l/min m^2 (15 to 50 gpm/ft^2). The second filter was comprised of 91 cms (36 in) of coarse garnet. Two-hour run lengths were attained at 407 l/min m^2 (10 gpm/ft^2) with SS removals of 80 to 95 percent and BOD_5 removals of 50 to 80 percent. The higher removals were attained with chemical treatment (150 mg/l alum + 4 mg/l flocculant aid). Flux rates of 814 l/min m^2 (20 gpm/ft^2) resulted in one-half hour runs. The third filter consisted of 1.2 m (48 in) of medium garnet and 23 cm (9 in) coarse garnet operated in an upflow mode. This filter maintained flux rates of 204 to 610 l/min m^2 (5 to 15 gpm/ft^2) with SS removals of 60 percent and BOD_5 removals of 45 percent. Efficiency dropped sharply for flux rates above 610 l/min m^2 (15 gpm/ft^2).

Filtration of CSO was studied at Cleveland, Ohio by Nebolsine et al. (14), where the filtration was preceeded by fine mesh screening (40 mesh). After testing anthracite sizes of Numbers 2, 3, and 4, a filter media configuration of 1.5 m (5 ft) of No. 3 anthracite (4.0 mm e.s.)over 0.9 m (3 ft) of No. 612 sand (2.0 mm e.s.) was chosen. Results without chemical treatment indicated average SS removals of 65 percent. The performance of the system decreased as the flux increased from 407 to 1628 l/min m^2 (10 to 40 gpm/ft^2). SS removal efficiencies of 90 and 95 percent were attained for respective flux rates of 1017 and 326 l/min m^2 (8 and 25 gpm/ft^2) with the addition of 1 mg/l of polyelectrolyte. Typical filter influent SS ranged from 114 to 301 mg/l. BOD_5 removals ranged from 23 to 62 percent without chemical and 54 to 72 percent with the addition of polyelectrolyte. Phosphorus removals averaged 26 to 52 percent with influent P concentration of 0.71 to 0.76 mg/l. Oil and grease removals ranged from 32 to 50 percent. Results were also presented for treatment with alum and polyelectrolyte. Typical run lengths were 6 to 10 hours at 977 l/min m^2 (24 gpm/ft^2) with no chemicals and 3 to 6 hours with polyelectrolyte. The filtration tests without chemical addition were terminated by headloss development while the polyelectrolyte runs generally resulted in termination due to solids breakthrough.

Filtration studies of CSO at Syracuse (36) used filtration through No. 3 anthracite, -16 +50 mesh clinoptilolite, and 3.2 mm (0.125 in) plastic pellets (37). When employing alum and polymer treatment, SS removal rates of 90 to 100 percent were achieved at application rates of 407 to 529 l/min m^2 (10 to 13 gpm/ft^2). Phosphorus removal increased from 30 to 98 percent as the Al:P molar ratio was increased from 0.5 to 3.5.

Backwash water requirement is a function of the filter media used. The Cleveland study (14) showed backwash requirements of 1.9 to 8.6 percent of filtered flow with a median value of approximately 4 percent. Backwash rates of 1261 to 3663 l/min m^2 (31 to 90 gpm/ft^2) were used with durations of 4 to 25 minutes. It is generally agreed that filters designed for wastewater treatment should incorporate both air scour and surface wash facilities. The Syracuse studies using No. 3 anthracite recommended 5 minutes of air scour at 1.2 m^3/min m^2 (4 scfm/ft^2), 3 minutes of scour-backwash at 1.2 m^3/min m^2 (4 scfm/ft^2) and 814 l/min m^2 (20 gpm/ft^2), respectively, followed by 12 minutes of backwashing at 814 l/min m^2 (20 gpm/ft^2).

OUTLINE OF EXPERIMENTS

The dual-media high-rate filter (DMHRF) experiments included evaluations of the effects of hydraulic loading and chemical treatment on performance. Flux rates of 407, 610, 814 and 1017 l/min m^2 (10, 15, 20 and 25 gpm/ft^2) were employed. Chemical treatments included: no chemicals, polyelectrolyte only (1 mg/l - Nalcolyte 676) and alum (30 mg/l) plus polyelectrolyte (1 mg/l).

The swirl separator effluent was used as influent to the DMHRF. Since several chemical treatments were employed on the swirl separator system, DMHRF performance is related to the upstream swirl treatment as well as the chemicals applied to the filter influent. Table 22 is a summary of the flux rates and chemical treatments associated with each filter run.

TABLE 22. DMHRF OPERATING CONDITIONS

Run No.	Filter No.	Flux (gpm/ft^2)	Chemicals On Swirl Separator*	Chemicals On DMHRF*
5-1	1	25	None	None
"	2	10	"	"
"	3	20	"	"
6-1	1	25	"	"
"	2	10	"	"
"	3	20	"	"
6-2	1	20	"	"
"	2	15	"	"
"	3	10	"	"
7-1	1	25	"	"
"	2	10	"	"
"	3	20	"	"
7-2	1	20	"	"
"	2	15	"	"
"	3	10	"	"
7-3	1	10	"	"
"	2	25	"	"
"	3	15	"	"
7-4	1	15	"	"
"	2	15	"	"
"	3	15	"	"
8-1	1	25	Polymer	"
"	2	10	"	"
"	3	20	"	"
8-2	1	20	"	"
"	2	15	"	"
"	3	10	"	"
8-3	1	10	"	"
"	2	25	"	"
"	3	15	"	"
9-1	1	25	"	"
"	2	20	"	"
"	3	10	"	"
9-2	1	10	"	"
"	2	15	"	"
"	3	25	"	"
9-3	1	20	"	"
"	2	10	"	"
"	3	15	"	"
9-4	1	25	"	Polymer
"	2	20	"	"
"	3	10	"	"

(continued)

TABLE 22. (continued)

Run No.	Filter No.	Flux (gpm/ft^2)	Chemicals Swirl Separator*	Chemicals On DMHRF*
9-5	1	25	Polymer	Alum + Polymer
"	2	20	"	"
"	3	10	"	"
11-1	1	15	Alum + Polymer	"
"	2	15	"	"
"	3	15	"	"
12-1	1	15	"	None
"	2	15	"	Polymer
"	3	25	"	"
12-2	1	15	"	Alum + Polymer
"	2	15	"	None
"	3	15	"	"
13-1	1	25	Phos. + Alum + Polymer	Alum + Polymer
"	2	25	"	Polymer
"	3	25	"	None
13-2	1	20	"	Alum + Polymer
"	2	20	"	Polymer
"	3	20	"	None
13-3	1	15	"	Alum + Polymer
"	2	15	"	Polymer
"	3	15	"	None
15-1	1	25	"	Polymer
"	2	25	"	"
"	3	25	"	None
15-2	1	15	Phos. + Alum + Polymer	Polymer
"	2	15	"	"
"	3	15	"	None
16-1	1	25	"	"
"	2	25	"	"
"	3	25	"	"
16-2	1	25	"	Polymer
"	2	25	"	"
"	3	25	"	"
17-2	1	15	None	"
"	2	15	"	"
"	3	15	"	"
17-3	1	15	"	"
"	2	15	"	"
"	3	15	"	"
17-4	1	15	"	None
"	2	15	"	"
"	3	15	"	"

*Chemical dosages: alum, 30 mg/l; polymer, 1 mg/l

The filter media consisted of 0.9 m (3 ft) of No. 2 anthracite over 1.5 m (5 ft) of No. 1220 sand. Following storm No. 8, the filters were regraded by hydraulically scalping the fines from the surface in an attempt to attain longer run lengths. Sieve analyses indicated size distributions of No. 2 anthracite (effective sizes and uniformity coefficients) for samples taken from the top of the filters as shown on Table 23.

TABLE 23. SIEVE ANALYSIS OF FILTER MEDIA

	Filter No.	Effective * Size (mm)	Uniformity Coefficient
No. 2 Anthracite		2.7	1.30
a. before regrading	1	1.7	1.69
	2	1.4	1.61
	3	1.3	1.52
b. after regrading	1	2.1	1.48
	2	1.8	1.39
	3	1.7	1.35

*Since the samples were taken from the top of the hydraulically classified bed, the effective size would be expected to be slightly finer than the unclassified media.

Filter runs were terminated upon headloss development of approximately 0.145 N/mm^2 (21 psi), 14.8 m of water (48.5 ft water). Headlosses were determined from pressure gauge readings taken at the top of the bed, and at the locations of 61, 152, and 244 cm (24, 60 and 96 in) below the top of the bed. Headlosses were corrected for static pressures at each location.

OPERATING PROCEDURES

The filter units were prepared for service by backwashing at 80 to 90 percent bed expansion. Backwash was preceeded by air scour at 0.6-1.5 m^3/min m^2 (2-5 ft^3/min ft^2) plus backwash at 2279 l/min m^2 (56 gpm/ft^2) for five minutes followed by an additional 10 minute backwash at 2890 l/min m^2 (71 gpm/ft^2).

Three parallel filters were operated with each run set. The units initially contained clean water to prevent channel formation on start-up. Flowrate was controlled by regulating a pump drawing wastewater from an effluent sump. A float valve on the column effluent thus regulated flow through the filter equal to the rate of sump withdrawal. Applied flowrate was constant throughout each entire run.

Pressure readings at each of four locations were taken every 15 minutes. Grab samples of influent, effluent and intermediate locations were taken at 15 to 30 minute intervals. Intermediate samples were taken at depths of 24 and 60 inches from the top of the media.

RESULTS

Figure 34 is a typical performance plot of data from the DMHRF system. Headloss and SS data are shown versus time. It is noted that the majority of the headloss occurred within the top 61 cm (24 in) of media. It is also noted that a gradual deterioration of effluent quality was obtained toward the end of this run. This is typical of the trend reported in the Cleveland study (14) for treatment with polyelectrolyte.

Run Lengths

Figures 35 through 37 show run lengths versus applied flux for several chemical treatment cases. In general, the results indicate the classical trend of reduced run lengths at higher flux rates. It is noted, however, that the upstream treatment (swirl separator) had a definite impact on the run lengths attained. Use of polymer and alum + polymer on the swirl separator unit tended to result in longer run lengths on the DMHRF. There may be two reasons for the longer runs. First, longer runs would be expected when lower SS concentrations are applied to the filters. However, as noted in Section 6, the chemical treatments on the swirl unit generally did not result in imporved performance across that unit. More likely, the longer filter runs were associated with the effluent solids from the swirl unit being chemically conditioned further ahead of the filter units.

Specific Capture

Measurements of filter run lengths do not allow assessment of the effects of changes in influent SS concentrations and the effects of attaining greater removal efficiencies. For these reasons the use of specific capture is a better indicator of performance.

Specific captures were determined by summing the incremental SS removals across the DMHRF for the duration of the filter runs. Results were calculated as total kg (or lb) of SS accumulated per m^2 (or ft^2) of surface area per run. Although the capture is expressed per unit of surface area, this does not necessarily imply that solids are only captured at the surface of the bed.

Figures 38 and 39 show specific captures versus flux rates. The most significant point immediately evident from these figures is that specific capture generally increases in most cases as flux rate is increased. It is characteristic of deep-bed filters that higher flux rates promote deeper penetration of solids into the interior of the bed and permit fuller utilization of the filter volume. However, as demonstrated below, higher flux rates also result in a greater rate of solids contamination of the effluent, so that tradeoffs must be evaluated.

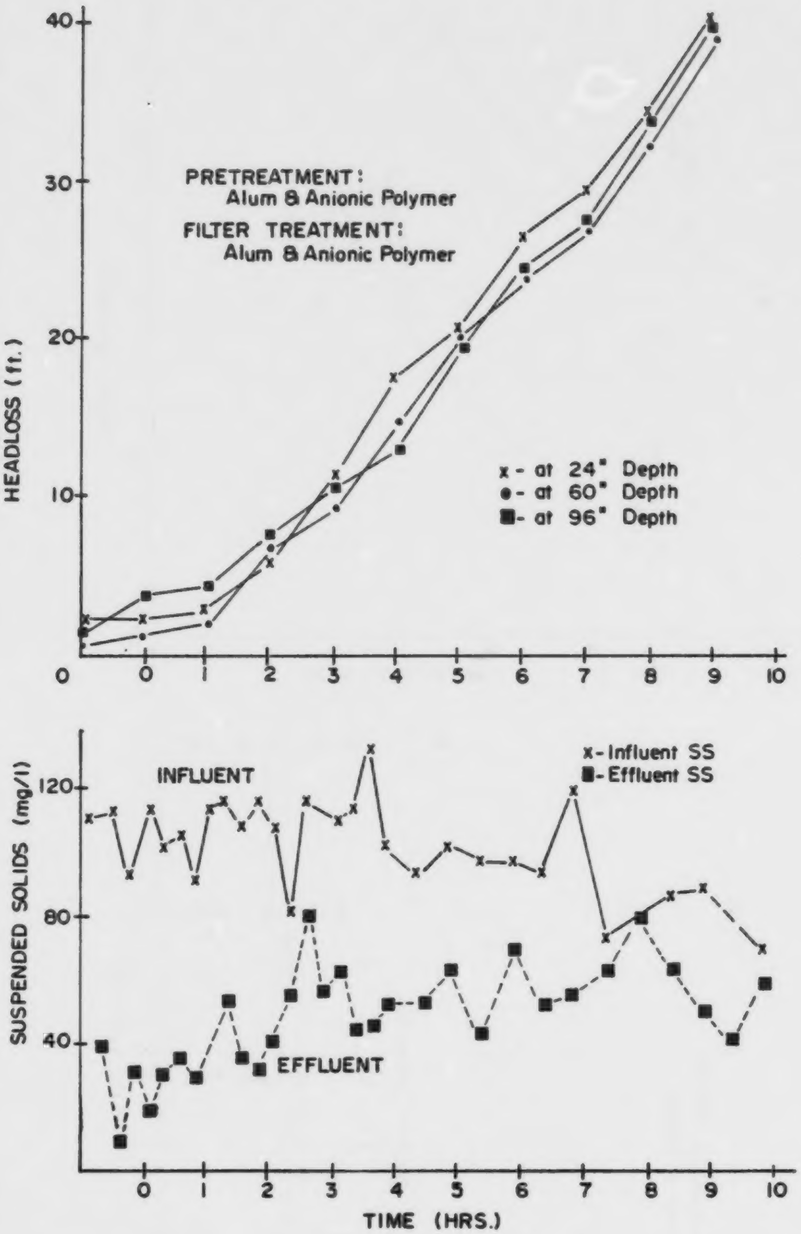


FIGURE 34. TYPICAL FILTER (DMHRF) PERFORMANCE CURVES
Run No. 11-2-2. Flux = 15 gpm/ft^2

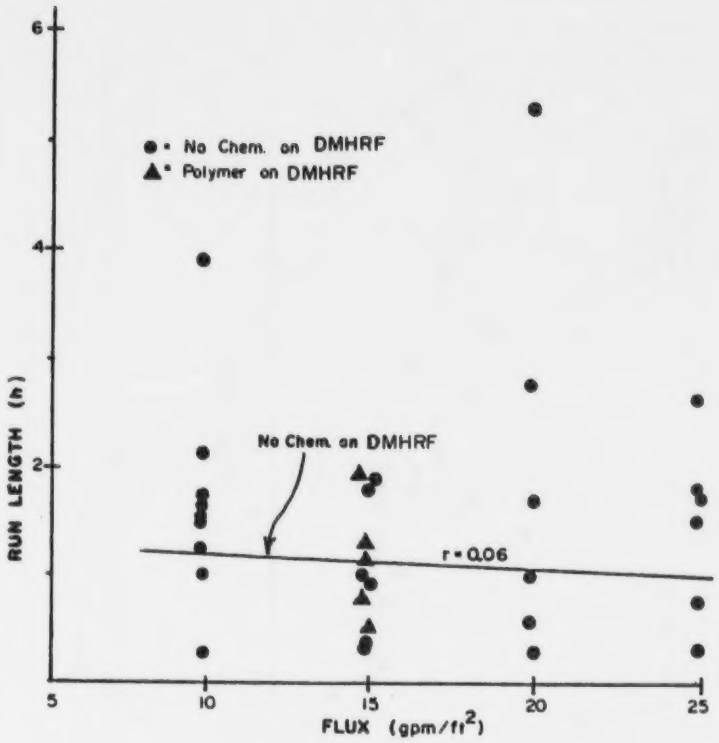


FIGURE 35. DMHRF Run Lengths. No chemical treatment on Swirl Primary Separator

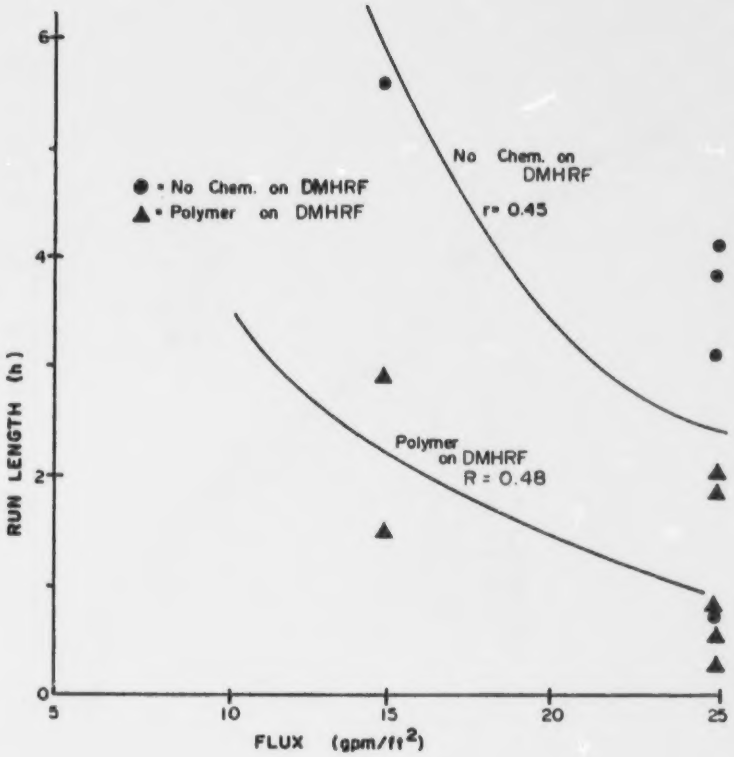


FIGURE 36. DMHRF Run Lengths. Alum + Polymer Treatment on Swirl Primary Separator

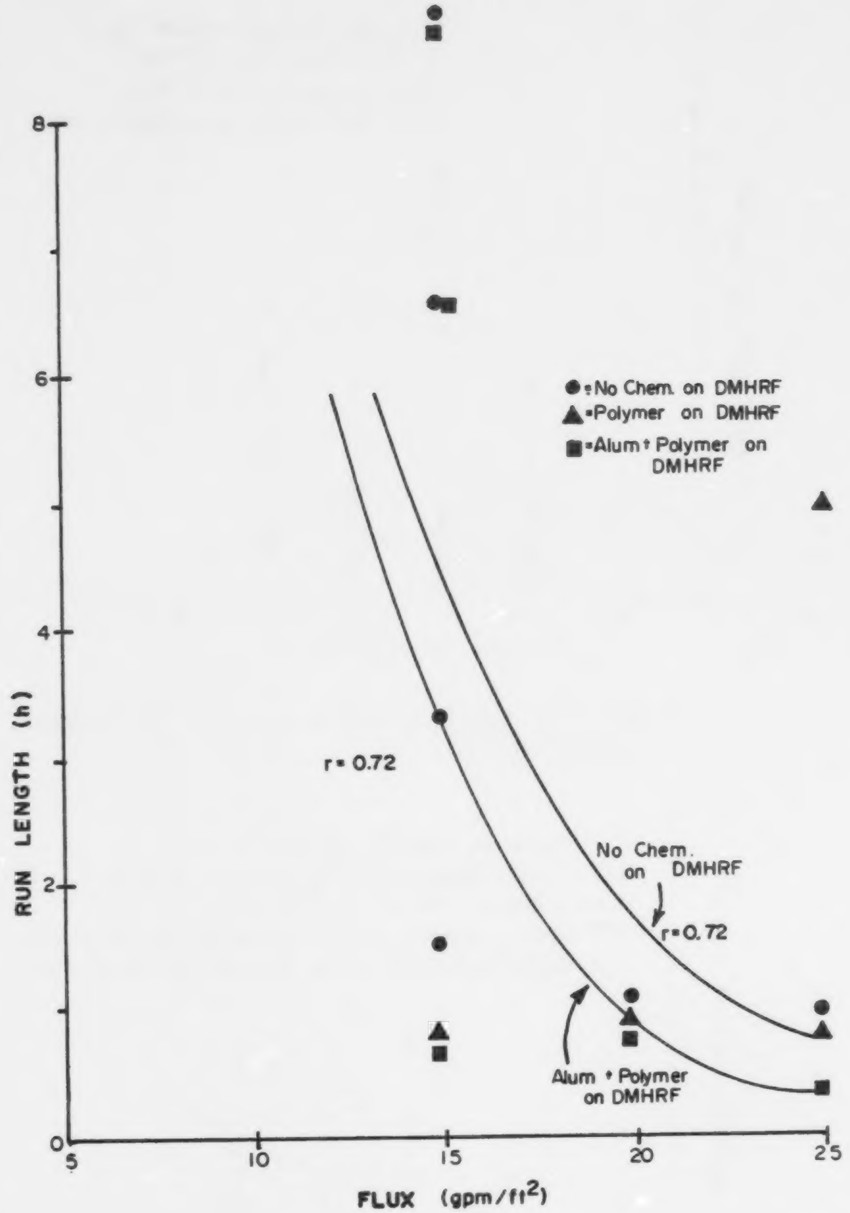


FIGURE 37. DMHRF Run Lenths. Polymer on Swirl Primary Separator

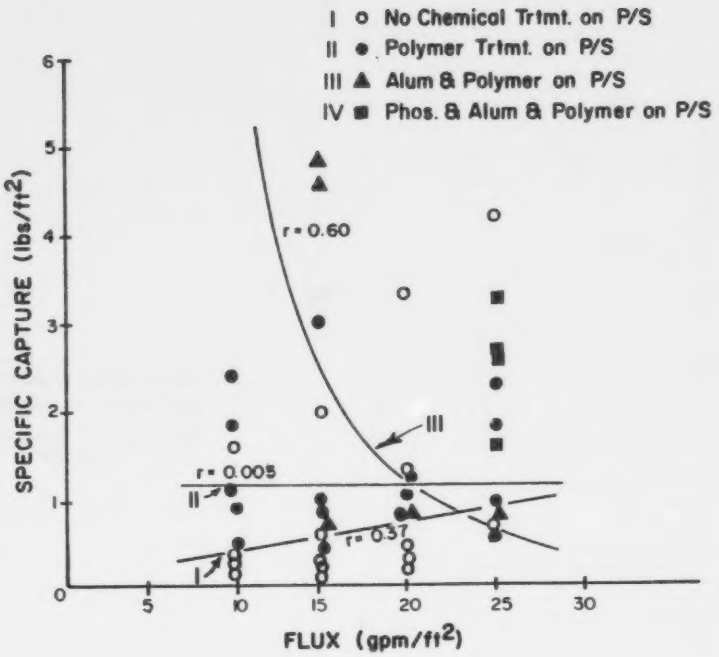


FIGURE 38. DMHRF Specific Capture. No Chemical Treatment on DMHRF.

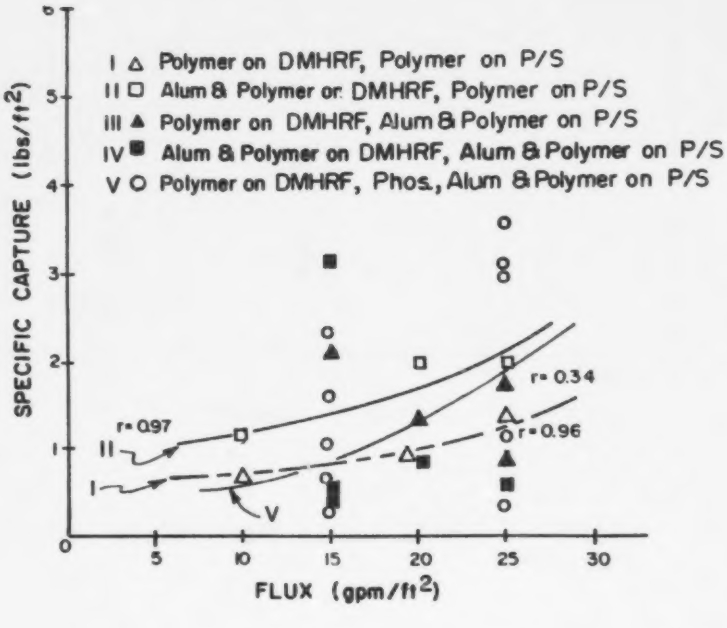


FIGURE 39. DMHRF Specific Capture. Chemical Treatment on DMHRF.

Figures 38 and 39 demonstrate the impact of the chemical treatments employed in the upstream swirl primary separator. Specific captures on the order of 9.8 kg/m^2 (2 lb/ft^2) per run were attained when alum + polymer were employed upstream. Comparison of Figure 38 to Figure 39 suggests that upstream chemical treatment had more impact on DMHRF performance than the chemicals applied directly ahead of the DMHRF. This points out the importance of contact time for chemical conditioning of CSO solids.

SS Removal Rates

Figures 40 and 41 show the effect of flux rate on percent removals of SS. In general, average percent SS removals decrease as the flux rate is increased. Figure 40 represents results for DMHRF runs where no chemicals were applied to the DMHRF. Figure 41 includes results for DMHRF runs employing chemical treatment. Again, the upstream chemical treatment on the swirl unit shows more significant effect on DMHRF performance than the chemicals applied to the DMHRF. SS removals generally ranged from 60 to 85 percent at 408 l/min m^2 (10 gpm ft^2) to 40 to 80 percent at 1018 l/min m^2 (25 gpm/ft^2). Best removals were attained when alum plus polyelectrolyte were applied to the swirl unit and/or the DMHRF.

Removal of Other Constituents

Statistical analyses of other parameters tested during the DMHRF runs are included in Appendix D for influent and effluent samples. Results of all tests of similar flux and chemical treatment (both swirl unit and DMHRF) were grouped for this analysis. Appendix D includes minimum, maximum, average, geometric mean,and standard deviation for each data set. The influent and effluent geometric mean (or median) data are compiled on Table 24 and median removals are listed for each set of flux and chemical treatment employed.

VSS removals ranged from 30 to 61 percent without chemicals and 43 to 96 percent when chemicals were employed. BOD_5 removals ranged from 32 to 56 percent without chemicals and 20 to 92 percent with chemicals. TOC removals were generally higher than COD removals. TOC removals ranged from 19 to 50 percent without chemicals and 23 to 68 percent with chemical treatment. COD removals averaged 13 percent without chemicals and 42 percent with chemicals.

Oil and grease removals were less than 4 percent without chemicals and ranged from 5 to 56 percent when chemical treatments were employed. TKN removals ranged from 8 to 13 percent without chemicals and 1 to 49 percent with chemicals. TIP removals of 7 to 34 percent were attained without chemicals, while chemical treatments generally resulted in TIP removals of 20 to 89 percent. Effluent pH ranged from 6.8 to 7.2 when chemicals were not employed and from 3.6 to 7.4 when chemicals were employed. Aluminum reductions were 10 to 93 percent without chemicals and 12 to 94 percent with chemical addition.

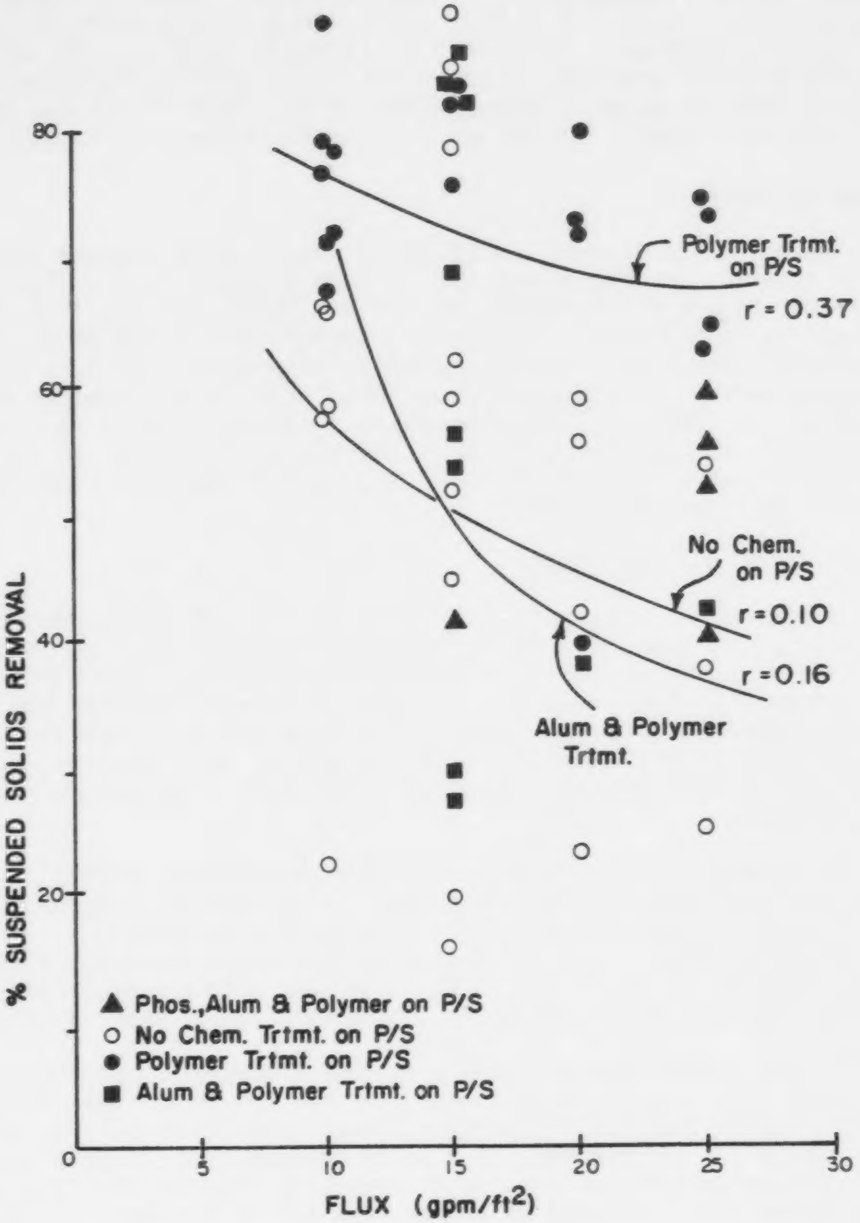


FIGURE 40. DMHRF Performance. No Chemical Treatment.

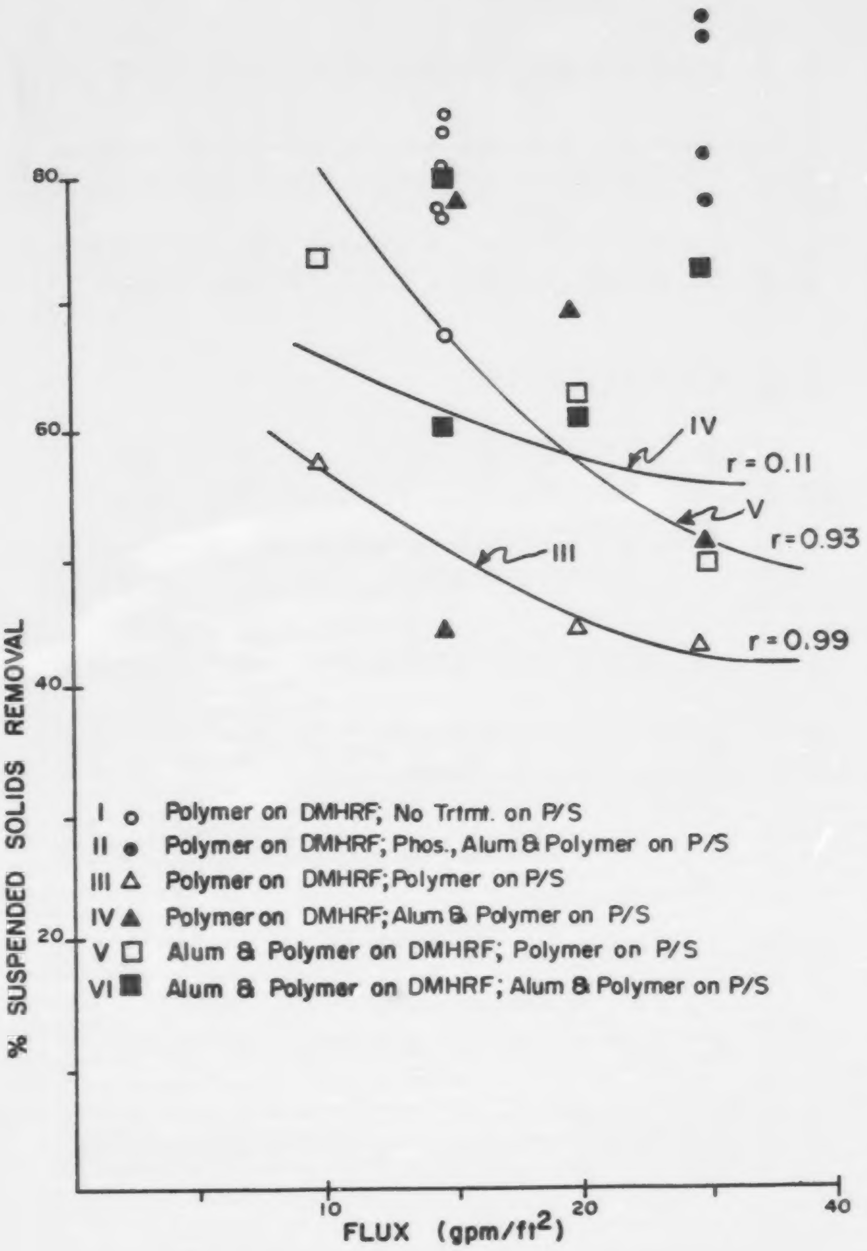


FIGURE 41. DMHRF Performance with Chemical Treatment.

TABLE 24. MEDIAN PERFORMANCE OF DMHRF

Treatment* On		Flux	SS			VSS			BOD$_5$			TOC		
P/S	DMHRF	gpm/ft^2	Inf. mg/l	Eff. mg/l	% Rem.	Inf. mg/l	Eff. mg/l	% Rem.	Inf. mg/l	Eff. mg/l	% Rem.	Inf. mg/l	Eff. mg/l	% Rem.
NC	NC	10	58.8	25.3	56	26.6	10.5	61	15.3	6.67	56	18.8	13.4	29
NC	NC	15	56.1	24.5	56	26.6	13.2	50	16.0	10.90	32	17.8	12.6	29
NC	NC	20	70.5	38.9	45	30.9	16.9	45	17.7	10.00	44	20.7	10.3	50
NC	NC	25	53.6	31.3	42	25.1	17.5	30	12.5	7.50	40	19.5	15.7	19
NC	PO	15	142.7	28.2	80	82.4	18.4	78	76.5	6.00	92	35.7	18.0	50
PO	NC	10	203.4	45.8	77	61.9	14.3	77	26.7	7.70	71	32.5	11.3	65
PO	NC	15	187.4	31.9	83	54.6	11.1	80	24.9	5.80	77	29.8	9.4	68
PO	NC	20	240.3	85.5	64	80.5	30.1	63	24.0	19.10	20	42.4	17.2	59
PO	NC	25	196.5	57.8	71	57.9	17.6	70	28.9	6.80	76	30.4	11.9	61
PO	PO	10	229.2	78.7	66	71.4	21.3	69	12.6			37.2	17.1	54
PO	PO	20	217.4	117.1	46	70.1	39.9	43	12.2			37.4	22.3	40
PO	PO	25	217.4	119.5	45	70.1	34.0	51	11.5			37.4	24.1	36
PO	AP	15	185.6	39.8	79	35.9	6.8	81	11.5			33.1	15.1	54
PO	AP	20	185.6	66.1	64	35.9	9.1	75	11.5			33.1	20.3	39
PO	AP	25	185.6	80.1	57	35.9	18.9	47	27.6			33.1	19.4	41
AP	NC	15	104.6	40.1	62	40.2	15.5	61	21.4	17.40	37	34.1	24.8	27
AP	NC	20	192.6	114.1	41	79.8	42.9	46	27.9			53.0	39.6	25
AP	NC	25	87.9	52.4	40	31.3	14.3	54	27.6	19.50	30	26.8	20.2	25
AP	PO	15	98.4	7.7	92	38.4	2.3	94	27.6	17.10		31.4	12.3	61
AP	PO	20	192.6	47.7	75	79.8	17.0	79	21.4			53.0	29.1	45
AP	PO	25	161.1	8.1	95	54.0	2.3	96	29.5	24.30		39.7	14.0	65
AP	AP	15	152.6	42.9	72	54.4	15.6	71	23.1	17.20		46.2	19.0	59
AP	AP	20	192.6	62.5	68	79.8	23.5	71	21.4			53.0	31.2	41
AP	AP	25	205.7	82.3	60	85.6	35.8	58	34.7			43.0	33.0	23

(continued)

*NC - no chemical treatment
PO - polymer treatment only
AP - alum + polymer treatment

TABLE 24. (continued)

Treatment* On P/S	Treatment* On DMHRF	Flux gpm/ft^2	COD Inf. mg/l	COD Eff. mg/l	COD % Rem.	O & G Inf. mg/l	O & G Eff. mg/l	O & G % Rem.	TKN Inf. mg/l	TKN Eff. mg/l	TKN % Rem.	TIP Inf. mg/l	TIP Eff. mg/l	TIP % Rem.
NC	NC	10	18.7	17.5	5				0.95	1.10		0.14	0.13	7
NC	NC	15	17.3	13.4	23	58.0	55.8	4	0.91	2.10		0.12	0.17	
NC	NC	20	20.7	18.2	12				1.19	1.03	13	0.16	0.10	34
NC	NC	25	18.5	18.8					1.03	1.38		0.15	0.15	
NC	PO	15				55.6	53.4	5	4.10	3.40	17	0.29	0.23	22
PO	NC	10	20.4	17.0	17				2.80	1.80	35	0.56	0.33	41
PO	NC	15	15.2	13.7	10				2.80	1.42	49	0.61	0.22	64
PO	NC	20	53.5	30.9	42				2.20	1.80	18	0.67	0.30	55
PO	NC	25	20.4	22.4					2.80	1.68	40	0.51	0.20	60
PO	PO	10							2.03	1.72	15	1.34	0.37	72
PO	PO	20							1.83	1.69	8	1.34	0.22	84
PO	PO	25							1.83	1.82	1	1.34	0.75	44
PO	AP	15							2.23	1.81	19	1.49	0.58	61
PO	AP	20							2.23	1.78	20	1.49	0.19	87
PO	AP	25							2.23	1.75	22	1.49	0.23	85
AP	NC	15				27.6	24.4	12	3.94	3.50	11	0.45	0.32	29
AP	NC	20				40.8	26.8	34	8.91	7.82	12	2.27	1.50	34
AP	NC	25				31.6	18.0	43	2.90	2.06	29	0.20	0.27	
AP	PO	15				27.6	12.1	56	4.03	3.36	17	0.42	0.09	79
AP	PO	20				40.8	20.0	51	8.91	7.90	12	2.27	0.67	70
AP	PO	25				30.8	15.6	50	2.76	2.40	13	0.85	0.23	73
AP	AP	15				37.4			4.82	2.80	42	0.89	0.10	89
AP	AP	20				40.8	24.0	41	8.9	8.30	7	2.27	0.99	56
AP	AP	25				86.0	40.8	53	8.2	8.05	2	1.60	1.28	20

(continued)

*NC - no chemical treatment
PO - polymer treatment only
AP - alum + polymer treatment

TABLE 24. (continued)

Treatment* On P/S	Treatment* On DMHRF	Flux gpm/ft^2	pH Inf.	pH Eff.	Al Inf. mg/l	Al Eff. mg/l	Al % Rem
NC	NC	10	7.01	7.03	0.70	0.52	26
NC	NC	15	7.16	7.20	0.45	0.03	93
NC	NC	20	6.89	7.08	0.86	0.51	41
NC	NC	25	6.94	6.80	0.72	0.65	10
NC	PO	15	6.92	7.00	0.60	0.05	92
PO	NC	10	7.16	7.25	2.53	0.71	72
PO	NC	15	7.20	7.14	3.10	1.90	39
PO	NC	20	7.16	7.28	1.52	0.82	49
PO	NC	25	7.10	6.95	2.60	0.16	94
PO	PO	10	7.35	7.40	2.53	0.85	66
PO	PO	20	7.30	7.42	2.70	1.55	43
PO	PO	25	7.30	7.28	2.70	1.56	42
PO	AP	15	7.19	7.11	1.83	0.77	58
PO	AP	20	7.19	7.37	1.83	1.83	
PO	AP	25	7.19	7.41	1.83	2.23	
AP	NC	15	6.23	6.38	16.55	12.10	27
AP	NC	20	4.07	4.15	96.00	80.50	16
AP	NC	25	6.53	6.51	10.82	6.97	38
AP	PO	15	6.08	6.57	12.17	4.63	76
AP	PO	20	4.07	4.15	96.00	67.10	30
AP	PO	25	6.18	6.42	12.88	7.56	41
AP	AP	15	5.51	6.64	33.63	3.97	88
AP	AP	20	4.07	4.10	96.00	76.20	21
AP	AP	25	3.40	3.60	98.90	87.00	12

*NC - no chemical treatment
PO - polymer treatment only
AP - alum + polymer treatment

SECTION 10

ACTIVATED CARBON ADSORPTION

BACKGROUND

The polishing of the effluent from the flocculation/sedimentation (F/S) and dual-media high-rate filtration (DMHRF) processes may be desirable and necessary to provide a secondary quality overflow effluent with respect to BOD_5 during wet-weather periods. Polishing of dry-weather flows at the VanLare plant may also be a direct benefit of having facilities designed to serve a dual purpose. The carbon facilities would be available to provide additional BOD_5 removal capability for dry-weather flows. During wet-weather conditions the carbon facilities could be switched over to provide treatment of the effluent directly related to either the CSO treatment tanks (flocculation/sedimentation basins) or, in the event of future plant expansion, the high-rate filtration process.

OUTLINE OF EXPERIMENTS

Evaluations of the carbon adsorption system were very limited. An outline of the experiments is presented in Table 25.

TABLE 25. ACTIVATED CARBON OPERATING CONDITIONS

Storm No.	Influent Origin	Detention Time (min)
13	DMHRF	45.0
16	F/S	13.5, 19.3, 30.0
17	F/S	13.5, 19.3, 30.0

Investigations conducted during Storm No. 13 were performed on filter effluent applied to the carbon columns at a rate of 0.19 l/s (3 gpm), which provided a detention time of 45 min at a surface flux of 57.4 l/min m^2 (1.41 gpm/ft^2). BOD_5 removal rates were evaluated for Storm No. 16 over a lower range of detention times (13.5, 19.3 and 30.0 min) with surface flux at 17.1-38.3 l/min m^2 (0.42-0.94 gpm/ft^2). These investigations were performed on the effluent from the F/S basin operating at 61.2 m^3/day m^2 (1500 gpd/ft^2) and chemically treated with alum and polymer.

BOD removal rates for Storm No. 17 were also evaluated over the same range of detention times and surface flux for Storm No. 16 and at a hydraulic loading rate of 81.6 m^3/day m^2 (2000 gpd/ft^2) on the F/S basin.

RESULTS

The major goal of pilot testing of the carbon adsorption system was to compare BOD_5 removal rates with detention time. BOD_5 removal results associated with Storm Nos. 16 and 17 are presented in Figures 42 and 43, respectively. Figure 42 showed a significant improvement in the removal of BOD_5 when the detention time was increased from 13.5 to 19.3 minutes. No improvement, however, was experienced when the detention time was further increased to 30 minutes.

The results depicted in Figure 43 suggest that for Storm No. 17, within the range of detention times investigated, variation in the detention time had minimal effect on the BOD_5 removal efficiency of the carbon facilities. The disparity between these results and those attained for Storm No. 16 may be attributed to the different influent BOD_5 levels experienced in each storm. Influent BOD_5 in Storm No. 16 ranged from 16 to 46 mg/l while those associated with Storm No. 17 ranged from 52 to 79 mg/l.

BOD_5 removal results for Storm No. 13 are shown in Figure 44. Influent BOD_5 experienced during this investigation were similar to those experienced in Storm No. 16. A comparison of the results from these two storms indicates that there was no enhancement in the BOD_5 removal efficiency when the detention time was increased beyond 30 minutes. This shows that for an influent BOD_5 range of approximately 15 to 50 mg/l, there appears to be an optimum detention time for BOD_5 removal between 13.5 and 30.0 minutes.

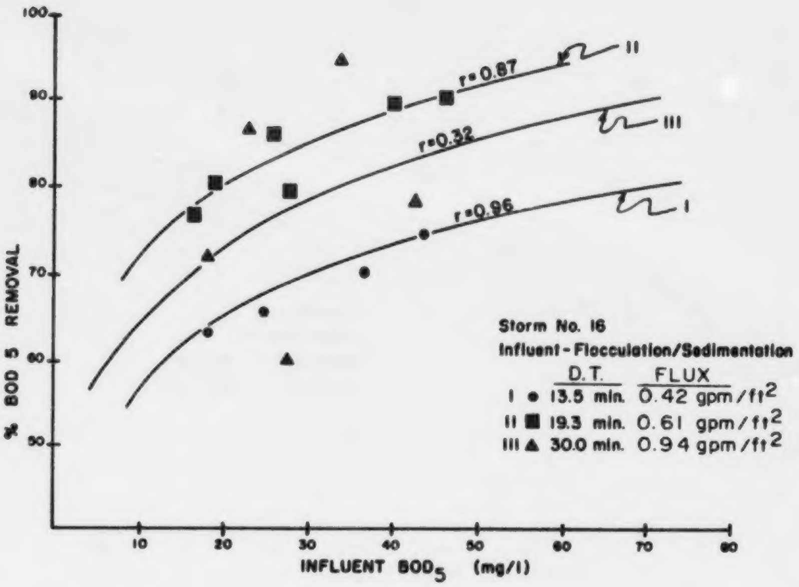


FIGURE 42. BOD$_5$ Removal with Carbon Adsorption. Low Influent BOD$_5$ concentration

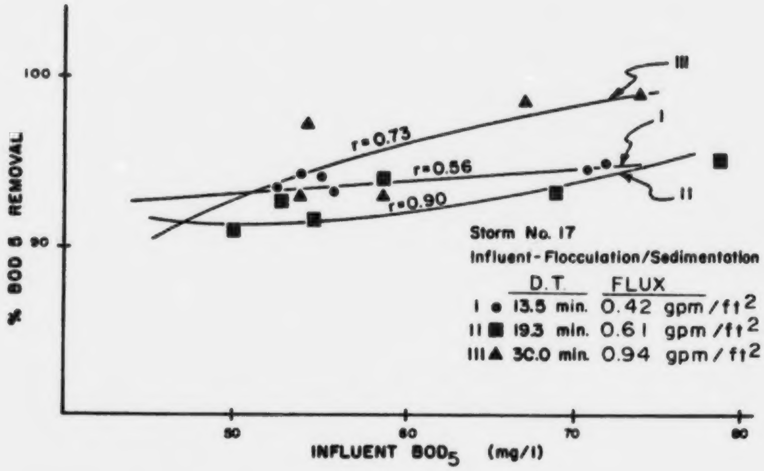


FIGURE 43. BOD$_5$ Removal with Carbon Adsorption. Higher Influent BOD$_5$ concentration

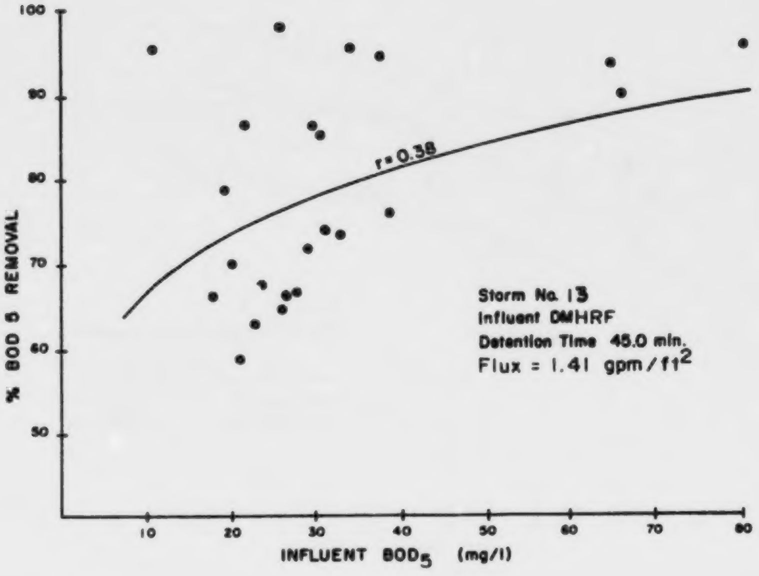


FIGURE 44. BOD$_5$ Removal With Carbon Adsorption

SECTION 11

HIGH-RATE DISINFECTION

BACKGROUND

Studies on disinfection of simulated combined sewer overflow (SCSO) in Syracuse, N.Y. (42) indicated that bacterial reductions occur rapidly in the presence of free chlorine (Cl_2). As the level of chlorine demanding substances in wastewater increases, the amount of free Cl_2 available as a bactericide significantly reduces. Ridenaur and Ingols (43) have hypothesized that chlorine dioxide (ClO_2) has an advantage over Cl_2 as a bactericide since it is less reactive with reduced substances present in wastewater.

The Syracuse studies (42) stated that the time of existence of free Cl_2 in the SCSO was very limited. They also reported that following the initial steep bacterial reduction brought about by the free Cl_2, there followed a gradual decrease in the bacterial population over an extended period of time. This second and lower rate of disinfection has been attributed to the combined form of Cl_2, which is considerably less powerful as a disinfection agent than free Cl_2. The work involving ClO_2 revealed that rapid bacterial kills were obtained within the first 30 seconds with little kill attained upon additional contact. It was concluded that ClO_2 itself is the disinfection species and its decomposition product ClO_2^- has very little disinfecting capability. It was also concluded that on a weight basis, ClO_2 is approximately twice as effective as Cl_2 in reducing bacterial populations to target levels. The Syracuse study (42) also observed an enhancement in the disinfection process with a two-stage (sequential) addition involving the application of Cl_2 followed by ClO_2 after an initial contact time of 15 to 30 seconds. It was hypothesized that this may be due to the regeneration of ClO_2 through the interaction of chlorite ion (ClO_2^-) and Cl_2.

Mixing has been shown to be a significant parameter in all disinfecting practices. In his report on a survey of a number of treatment plants in the San Francisco Bay area, White (44) found that all of the plants exhibiting good disinfection had good mixing.

The influence of mixing intensity on bacterial kills with Cl_2 has been demonstrated by Collin (45) and Kruse (46). The use of the velocity gradient (G) as a measure of the mixing intensity was first proposed by Camp and Stein (47) in 1943. More recently, the nondimensional expression, GT, has been associated with the effective mixing intensity. In this expression, G represents the velocity gradient and T is the nominal contact time in the disinfection chamber. Glover (26,49) reported that disinfection performance can be considered a function of the GT parameter and suggested that as the value of GT increases, disinfection is enhanced. Glover (49) also proposed the use of initial flash mixing and corrugated baffles in the disinfection chamber as an inexpensive means of increasing the GT value.

TEST PROGRAM

The intent of the disinfection program was to evaluate the performances of Cl_2 and ClO_2 in a high-rate disinfection application. Since CSO treatment involves capital facilities that are not operated full-time, it may be desirable to reduce the capital cost of the facilities at the expense of operating and chemical costs. If ClO_2 reacts faster and more effectively than Cl_2, as has been experienced in previously mentioned studies, the higher applied chemical cost associated with ClO_2 may be offset by lower capital costs.

As a result of the bench-scale studies on high-rate disinfection conducted in Syracuse, N.Y. (42), two-stage disinfection with Cl_2 and ClO_2 was evaluated in the Rochester pilot plant. It was considered possible that a more cost-effective alternative to single-stage disinfection could be developed if there were an improvement in the level of disinfection realized by two-stage application using Cl_2 and ClO_2.

The disinfection program also sought to define the type and level of mixing which is necessary to optimize the disinfection process. It was anticipated that if an optimum level of mixing could be established, it might prove advantageous to reduce capital costs by lowering process contact times.

The equipment involved in performing the disinfection studies is presented in Section 4. Testing was conducted in three parts. During storm events, the three disinfection systems were operated at three different dosage rates with all other conditions being identical. This allowed for the evaluation of the effect of the changes in chemical demand during the storm which could be attributed to organic and nitrogenous substances. This type of evaluation was conducted for both single-stage and two-stage disinfection. The latter part of the test program included the evaluation of different mixing conditions.

Following each storm, the disinfection systems were run using swirl primary separator and/or microscreen effluents collected prior to and following filtration. This allowed for further evaluations of the effects of solids levels on disinfection. In addition, the post-storm disinfection allowed for the evaluation of a larger array of dosages, detention times, and mixing conditions. During the holding period the quality of the stored wastewater remained relatively stable.

Part three of the disinfection studies included a number of tests utilizing dry-weather flow. These permitted the supplementary evaluation of the effect of chemical demand and solids loadings on the disinfection process.

Operating conditions for the wet- and dry-weather tests are outlined in Tables 26 and 27. The variables controlled in these tests were dosage, detention time, and mixing intensity.

TABLE 26. SUMMARY OF WET-WEATHER DISINFECTION OPERATING CONDITIONS

Storm No.	Influent Origin	D.T.[†††] (min)	Mixing	Cl_2 Dose (mg/l)	ClO_2 Dose (mg/l)
1-5	F/S*	1.8-5.6	CORR**	0	
6	F/S	1.8-5.6	CORR	0	2-12
	DMHRF	1.1-8.4	CORR	0	3-10
7	F/S	1.8-5.6	CORR	0	3-10
	DMHRF	1.1-8.4	CORR	0	2-9
8	F/S	1.8-5.6	CORR	0	2-9
	DMHRF	1.1-8.4	CORR	0	2-8
9	F/S	1.8-5.6	CORR	2-19	0
	DMHRF	1.1-8.4	CORR	6-19	0
10	F/S	1.8-5.6	CORR	4	0
11	F/S	1.8-5.6	CORR	4-14	0
12	F/S	1.8-5.6	CORR	6-15	0
	DMHRF	1.1-5.6	CORR	6-15	0
13	F/S	1.8-5.6	FM[††],SFM[§§],CORR	4	0
	DMHRF	1.8-5.6	FM SFM ,CORR	4	0
15	F/S	1.8-5.6	CORR	2	1,2,3
	DMHRF	1.1-5.6	CORR	2	1,2,3(Cl_2 First)
	DMHRF	1.8-5.6	FM,SFM,CORR	2	2
16	CC [§]	1.3-3.8	CORR	0	2,4,6
	DMHRF	1.1-3.4	FM,SFM,CORR	0	0
				4,6,8	4,6,8
17	CC	1.3-3.8	FM	4,6,8	0
	DMHRF	1.8-5.6	FM	0-12	0-6(Cl_2 First)

(continued)

TABLE 26. (continued)

Storm No.	Influent Origin	D.T. (min)	Mixing	Cl_2 Dose (mg/l)	ClO_2 Dose (mg/l)
18	F/S	1.8-5.6	FM,SFM,CORR	0	5
	P/S***	1.8-5.6	FM,SFM,CORR	0	4,6,8
				2,4,6	0
19	F/S	1.8-5.6	FM,SFM,CORR	1,2,3	1,2,3 (Cl_2 First)
	P/S	1.8-5.6	FM,SFM,CORR	1,2,3	1,2,3 (ClO_2 First)

*F/S - Flocculation/Sedimentation
†DMHRF - Dual-Media High-Rate Filter
§CC - Activated Carbon Columns
**CORR - Corrugated Baffles
†† FM- Single Flash Mix
§§SFM - Sequential Flash Mix
***P/S - Swirl Primary Separator
†††D.T. - Detention Time

TABLE 27. SUMMARY OF DRY-WEATHER DISINFECTION OPERATING CONDITIONS

Storm No.	Influent Origin	D.T. (min)	Mixing	Cl_2 Dose (mg/l)	ClO_2 Dose (mg/l)
65	F/S	1.8-5.6	CORR	4,6,8	0
66	F/S	1.8-5.6	CORR	4,6,8	2,4,6
69	P/S	1.8-5.6	CORR	4,6,8	0
			FM,SFM,CORR	1-4	1-4 (Cl_2 First)
70	P/S	1.8-5.6	FM,SFM,CORR	1,2,3	1,2,3 (ClO_2First)
76	P/S	1.8-5.6	FM	0	4,6
				6,8	0

SINGLE STAGE TREATMENT: CHLORINE VERSUS CHLORINE DIOXIDE

Multiple Regression Analysis

In order to evaluate the effects of the operating conditions and variable wastewater quality it was considered desirable to develop a mathematical model from the disinfection data. Multiple regression analysis was thus conducted to statistically fit an equation to the pilot plant data and to develop an optimal design configuration for treating CSO.

The final equation selected for the multiple regression analysis was:

$$\log \text{kill} = K_1 (C)^{K_2} (G)^{K_3} (DT)^{K_4} (10)^{K_5 \text{TKN} + K_6 \text{BOD}} \qquad (1)$$

where log kill = log Influent F. Coli-log Effluent F. Coli

C = concentration of disinfectant, mg/l

G = velocity gradient, min^{-1}

D.T. = detention time, min

TKN = concentration of TKN, mg/l

BOD = concentration of BOD_5, mg/l

K_1 through K_6 = constants

The relation between D.T. and log kill was based on the first-order relationship normally referred to as Chick's law (51), i.e.:

$$\frac{dN}{dt} = -kN \qquad (2)$$

where dN/dt = time rate of kill

k = rate constant

N = number of living microorganisms

Equation 2 may be rearranged (11) to yield:

$$t = \frac{2.3}{K} \log \frac{N_1}{N_2} \qquad (3)$$

where N_1 and N_2 = number of microorganisms living initially and at time, t, respectively.

Equation 3 suggested a linear relationship between the contact time and the log kill.

The relationship between the concentration of the disinfectant and the time required for the disinfection process has been suggested (52) as follows:

$$t = \frac{k''}{C^n} \qquad (4)$$

where t = time required to kill a given percentage of microorganisms

C = concentration of disinfectant

n = coefficient of dilution

k'' = constant

Equation 4 suggested the use of the factor C^K in the regression model (equation 1).

Use of the term, G, in equation 1 was based on a review of Glover's (49) work with high-rate disinfection of CSO. Examination of Figure 2 presented in reference 49 indicated a straight line relationship between the log (log kill) and the log GT:

$$\log (\log \text{kill}) = m \log GT \qquad (5)$$

where m = slope

GT = measure of mixing intensity, unitless.

Equation 5 can be further reduced to:

$$\log \text{kill} = (GT)^m = G^m T^m$$

where G = velocity gradient, t^{-1}

T = contact time

Most relationships developed in the literature between disinfectant dosage and kill are presented in terms of disinfectant residual. Disinfectant residual is a function of dosage as well as contact time and concentrations of reduced substances present in the wastewater (53). In order to develop a mathematical relationship between kill and dosage it was therefore necessary to include BOD_5 and TKN data, as these parameters affect the ability to maintain a disinfectant residual.

In addition to the variables presented in Equation 1, a number of other possible variables were tested in the multiple regression analysis. Changes in pH, temperature, suspended solids concentrations, and volatile solids concentrations did not show statistically significant effects with the disinfection system performance data.

Tables 28 and 29 present the results obtained from the regression analysis conducted on the Rochester pilot plant data. The regression coefficient values correspond to the exponential K values in equation 1. The value of K_1 in equation 1 is equal to 10^i where i is equal to the intercept value. The magnitude of the regression coefficient gives an indication of the relative importance of this term in the regression expression. In the case of disinfection by Cl_2, positive regression coefficients associated with the dosage, detention time, and velocity gradient signify that as these values increase, the value of the log kill also increases. The negative signs associated with the TKN and BOD indicate that as these values increase the value of the log kill decreases.

TABLE 28. MULTIPLE REGRESSION ANALYSIS RESULTS FOR DISINFECTION BY Cl_2

Variable	Mean	Standard Deviation	Correlation X vs Y	Regression Coefficient	Std. Error of Reg. Coef.	Computed T Value
Log C_1	0.820	0.193	0.605	0.662	0.059	11.21
Log T	0.511	0.202	0.110	0.456	0.119	3.82
C_2	3.80	2.56	-0.205	-0.00431	0.00433	-0.996
C_3	36.1	25.0	-0.503	-0.00456	0.00052	-8.83
Log (G)	4.43	0.193	-0.137	0.280	0.125	2.24
Dependent Log(Log $\frac{N_1}{N_2}$)	0.466	0.265				

Intercept	-1.37
Multiple Correlation	0.727
Std. Error of Estimate	0.183

Analysis of Variance for the Regression

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F Value
Attributable to Regression	5	10.74	2.14	63.7
Deviation from Regression	284	9.57	0.0337	
Total	289	20.3		

TABLE 29. MULTIPLE REGRESSION ANALYSIS RESULTS FOR DISINFECTION BY ClO_2

Variable	Mean	Standard Deviation	Correlation X vs Y	Regression Coefficient	Std. Error of Reg. Coef.	Computed T Value
Log C_1	0.525	0.216	0.548	0.628	0.0797	7.88
Log T	0.500	0.210	0.031	0.0781	0.139	0.560
C_2	3.17	1.16	0.157	0.00314	0.0139	0.224
C_3	25.1	13.6	-0.00719	-0.00719	0.00156	-4.61
Log (g)	4.42	0.201	-0.0241	0.0502	0.146	0.343
Dependent Log(Log $\frac{N_1}{N_2}$)	0.399	0.204				

Intercept	-0.0212
Multiple Correlation	0.698
Std. Error of Estimate	0.150

(continued)

TABLE 29. (continued)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F Value
Attributable to Regression	5	1.88	0.377	16.7
Deviation from Regression	88	1.98	0.0225	
Total	93	3.87		

Multiple regression analysis with the ClO_2 data also produced positive regression coefficients for the dosage, detention time, and velocity gradient and a negative regression coefficient for BOD_5. The magnitude of the standard error of the regression coefficient and the T value associated with the TKN indicate that the effect of this parameter is fairly insignificant.

The 'T' value designates the degrees of confidence with which the corresponding regression coefficients may be assumed to be statistically significant. In the case of Cl_2 disinfection, the 'T' values for the dosage, detention time, and BOD_5 correspond to a degree of confidence greater than 99.5 percent. The 'T' value associated with the velocity gradient, G, represents a degree of confidence greater than 95 percent, while that associated with the TKN indicates less than a 70 percent degree of confidence. The 'T' values associated with BOD_5 and the ClO_2 dosage indicate degrees of confidence greater than 95 percent each.

The 'T' values for ClO_2 disinfection associated with detention time, velocity gradient, and TKN represent degrees of confidence lower than 50 percent, 30 percent, 20 percent, respectively. These low values indicate that variations of these parameters did not account for variations in performance. The 'F' value in the multiple regression analysis gives an indication of the statistical significance of the entire regression expression. 'F' values associated with both the Cl_2 and ClO_2 regression analysis represent degrees of confidence greater than 99 percent.

The final regression equations obtained from the Rochester pilot plant data are as follows:

$$\log \text{kill} = .0422(C)^{.662}(G)^{.280}(DT)^{.456}(10)^{-.00431TKN-.00456BOD} \quad (6)$$

for Cl_2, and

$$\log \text{kill} = .952(C)^{.628}(G)^{.0502}(DT)^{.0781}(10)^{.00314TKN-.00719BOD} \quad (7)$$

for ClO_2.

Lists of the multiple regression analysis input data and the regression residuals for both Cl_2 and ClO_2 are presented in Appendix E.

Illustrative Trends of the Regression Model

Subsequent to their development, the regression models were used to investigate the separate effects of the independent variables on the disinfection unit performance. Variation in unit performance was first evaluated with respect to mixing intensity and detention time. Plots of performance versus GT were developed using detention times of 1, 4, and 30 minutes. These detention times were selected in an effort to compare the model results with the results Glover (49) obtained using a Cl_2 residual of 5 mg/l. A Cl_2 dosage of 8 mg/l in the Cl_2 regression model roughly corresponds to the Cl_2 residual of 5 mg/l used by Glover (49). The 4 mg/l ClO_2 dosage in the ClO_2 regression model is roughly comparable to an 8 mg/l Cl_2 dose. Values for TKN and BOD_5 used in this model analysis were the average values experienced in the Rochester studies.

Plots of Glover's (49) results along with the results obtained using the regression models are presented in Figure 45. A comparison of the curves for Cl_2 shows similar trends. The slope of these curves indicates that disinfection with Cl_2 is greatly enhanced with an increase in mixing intensity. The slope associated with the ClO_2 curve implies that additional mixing does not produce a very significant change in bacterial reductions when ClO_2 is used as the disinfectant. Figure 45 also suggests that at very low mixing intensities and short contact times, ClO_2 is more effective than Cl_2 in reducing bacterial populations.

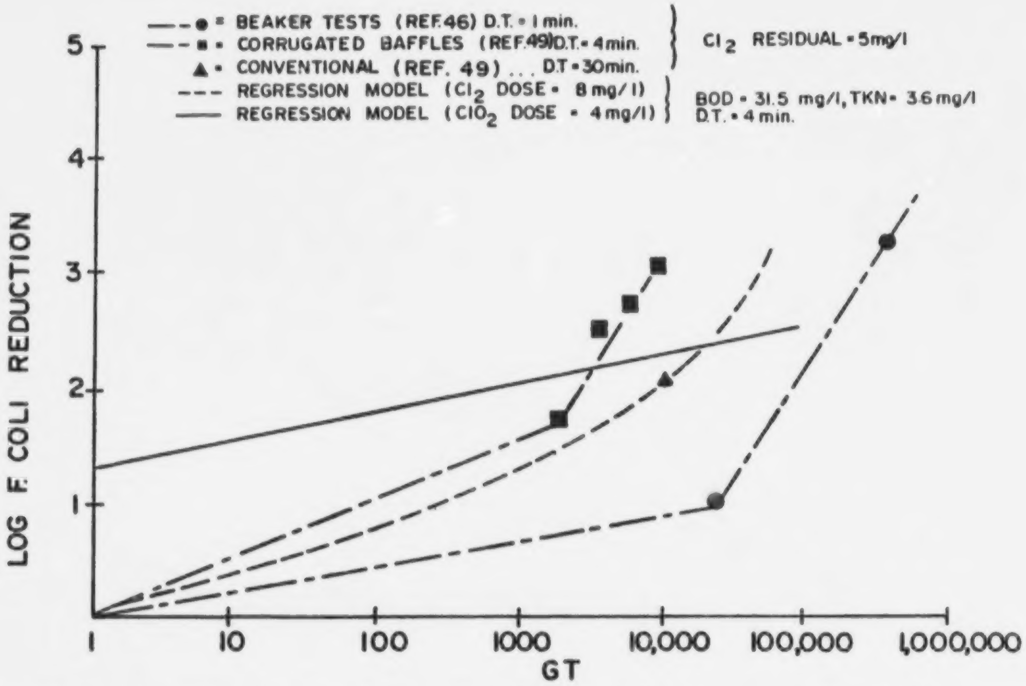


FIGURE 45. Comparison of Regression Model With Literature Results

Figure 46 is a plot of performance versus GT for different dosages of Cl_2 using the average TKN and BOD_5 values from the Rochester data. Apparent in Figure 46 is the influence of mixing intensity on Cl_2 disinfection effectiveness. This figure also suggests that there is a more pronounced effect on the performance when the Cl_2 dosage is varied at the higher mixing intensities.

A plot of performance versus GT for various ClO_2 dosages is presented in Figure 47 for average TKN and BOD_5 values. The slope of the curves indicates that mixing intensity has only a slight effect on the effectiveness of disinfection experienced with ClO_2. The distance between the curves suggests that increasing the ClO_2 dosage produces similar increases in bacterial kill, regardless of the mixing intensity. Comparison of Figures 46 and 47 shows ClO_2 to be a better disinfectant than Cl_2 at lower mixing intensities.

The effect of changing BOD_5 was the next area evaluated using the regression models. Figure 48 presents plots of performance versus dosage for both Cl_2 and ClO_2. BOD_5 values used in the analysis corresponded to half the average, the average, and twice the average of the BOD_5 values encountered in Rochester. Comparing the plots shows that lower dosages of ClO_2 are employed relative to those required when using Cl_2. The plots also indicate that variations in the BOD_5 level of the applied wastewater produce significant changes in the disinfection effectiveness of Cl_2 and ClO_2, the greatest sensitivity observed for ClO_2.

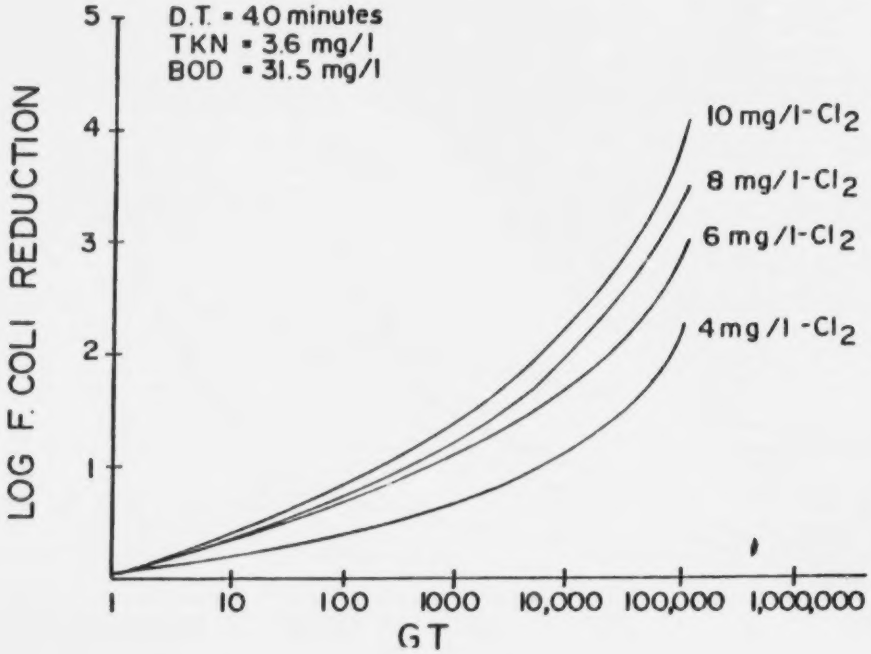


FIGURE 46. Effect of Cl_2 Dose in Regression Models

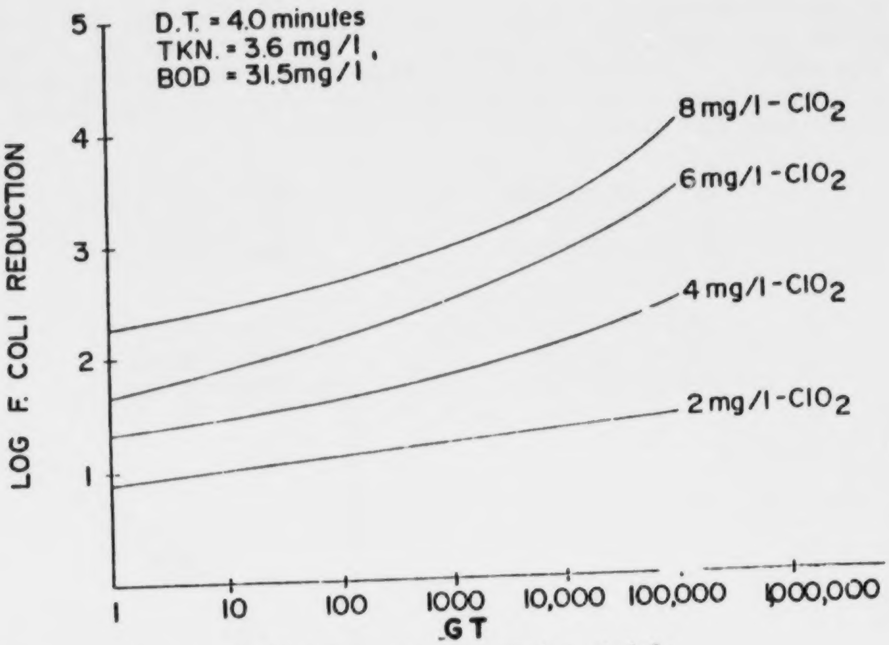


FIGURE 47. Effect of ClO_2 Dose in Regression Models

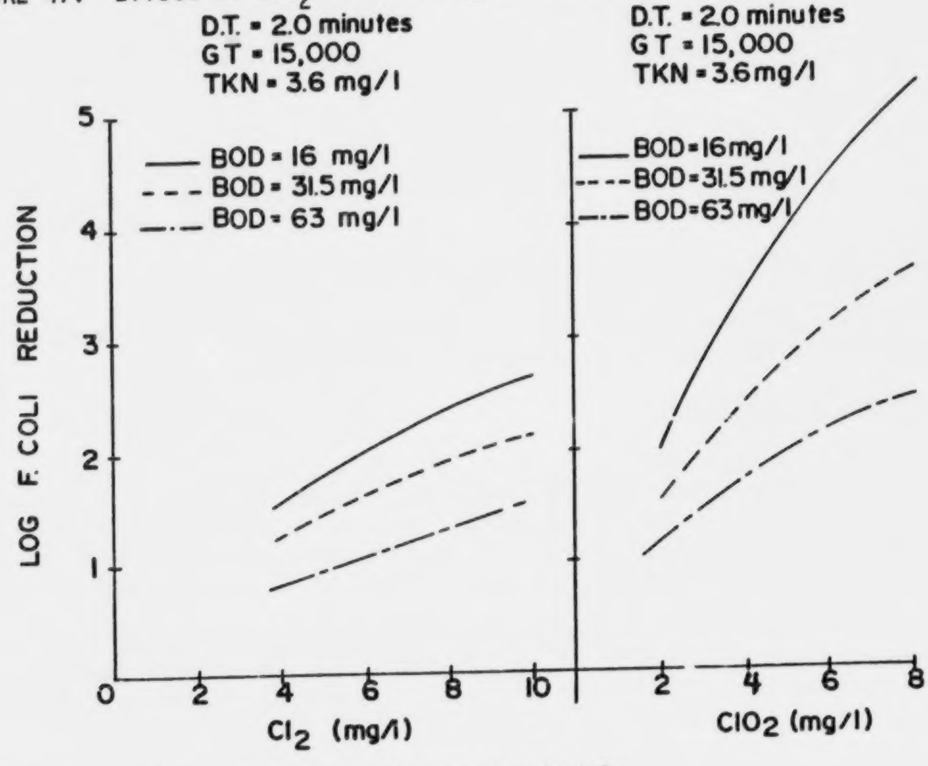


FIGURE 48. Effect of BOD_5 in Regression Models

A similar sensitivity analysis was conducted using the TKN information. Results of this analysis are presented in Figure 49. The set of curves for both Cl_2 and ClO_2 indicates that variation in the TKN levels produces a fairly insignificant effect on the bacterial reductions experienced with either of these two disinfectants.

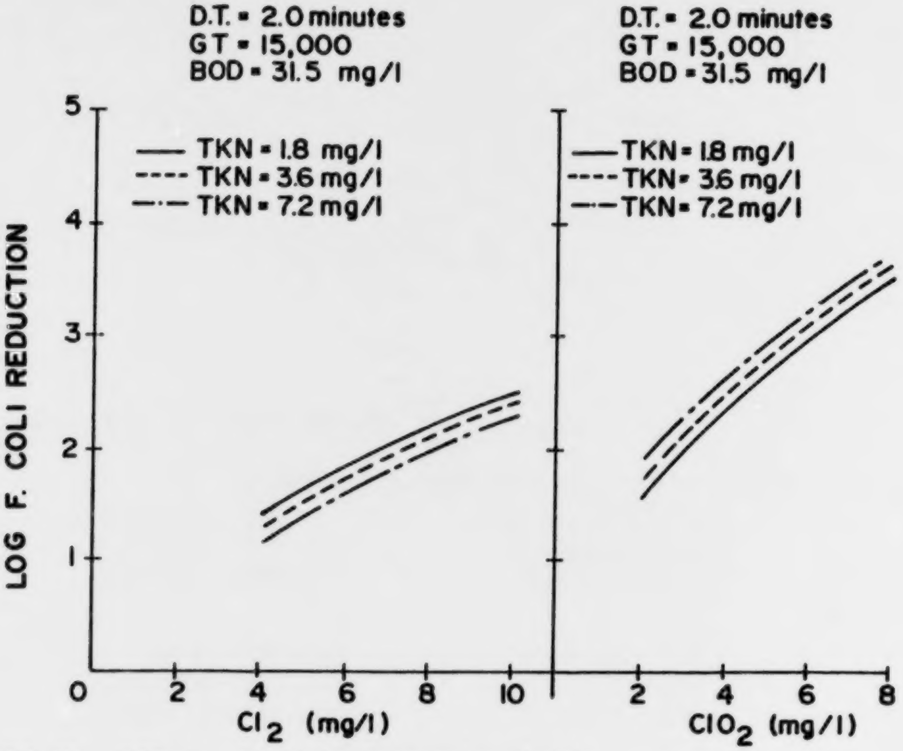


FIGURE 49. Effect of TKN in Regression Models

Figures 50 and 51 indicate the correlation between actual data and performance predicted by the regression equations.

Cost/Benefit Analysis

Design factors such as G, D.T., and dose affect both capital and operation/maintenance costs as well as the performance of the disinfection treatment facilities. It was the objective of the cost/benefit analysis to determine the combination of design factors necessary to develop the most cost-effective facility for the disinfection of combined sewer overflows.

Disinfection cost equations have been developed from the cost curves presented in reference (54). Capital costs for the disinfection facilities are presented as a function of the size of contact chamber and the amount of mixing provided. All costs have been adjusted to the ENR construction cost index of 2480.

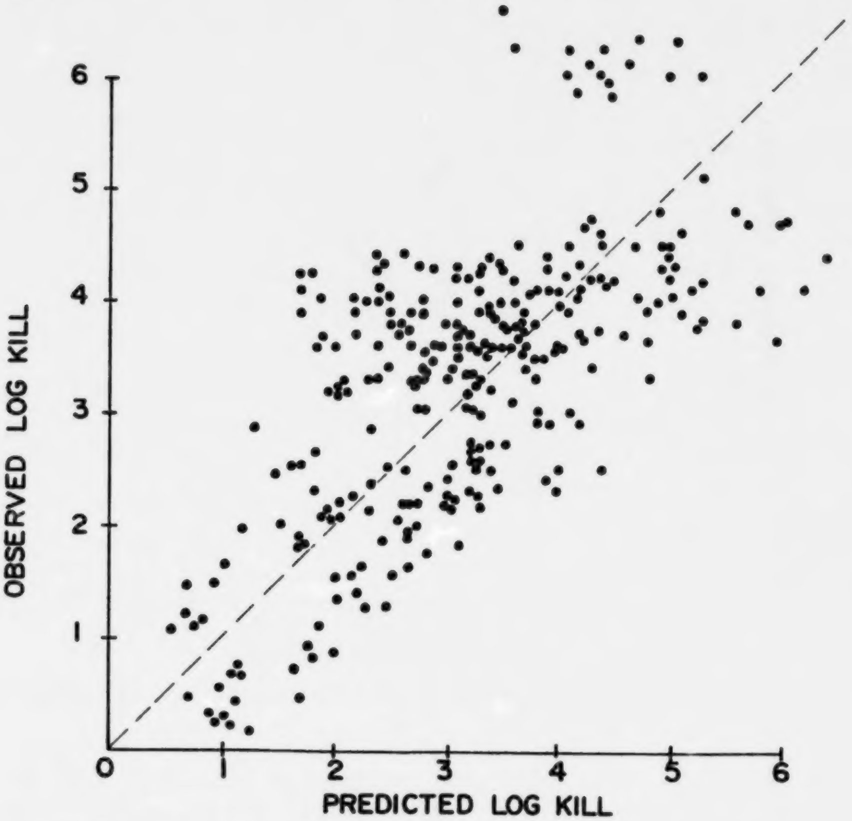


FIGURE 50. Predicted vs. Observed Bacterial Reductions for Chlorine

$$\text{CAPITAL COST (\$)} = 10.229\ (G)^{.5668}\ (V)^{.65} \qquad (8)$$

where G = velocity gradient, sec^{-1}

V = volume of contact chamber, ft^3

When the capital costs are amortized over 20 years at an interest rate of 6 percent, the following yearly cost is attained:

$$\text{CAPITAL COST (\$/yr)} = 0.89176\ (G)^{.5668}\ (V)^{.65} \qquad (9)$$

Using the cost curve relating manpower requirements to the size of a rapid mix basin, the following equation is developed:

$$\text{MAN-HOURS} = 0.04867\ (OF)^{.78031}(V)^{.633} \qquad (10)$$

where OF = number of overflow events per year

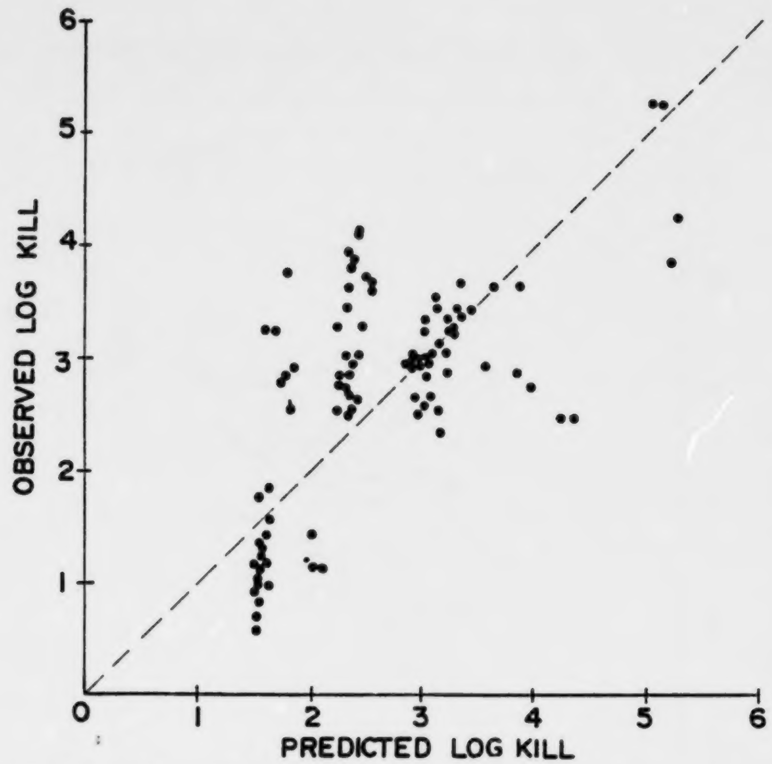


FIGURE 51. Predicted vs. Observed Bacterial Reductions for Chlorine Dioxide

For the purposes of the cost/benefit analysis, all overflows in the Rochester area under the application of the two-year design storm were considered eliminated and all wet-weather flow was assumed treated at central facilities. It was also assumed that a rainfall of 2.5 mm (0.10 in) would produce enough runoff to warrant the operation of these facilities. Averaging the number of days per year in which the rainfall in Rochester exceeded 2.5 mm (0.10 in) (1961-1975). Equation 10 yields:

$$\text{MAN-HRS/yr} = 1.4431\ (V)^{.633} \tag{11}$$

Assuming a manpower cost of \$15/hr, the final operation and maintenance cost equation becomes:

$$\text{O \& M COST (\$/yr)} = 21.646\ (V)^{.633} \tag{12}$$

Transformation of the material and supply cost curves produced the following:

$$\text{M \& S COST (\$/yr)} = 1.0768\ (V)^{.6404} \tag{13}$$

The expression relating costs to power requirements, assuming a charge of $.025/KWH, was found to be:

$$\text{PWR COST(\$/yr)} = \frac{G^2V}{257{,}875} \tag{14}$$

Chemical costs were based on a total yearly treatment of 17,600 m^3 (4651 mil gal), which corresponds to the average yearly quantity of wet-weather flow experienced in Rochester over the past ten years (1965-1975). Using a cost for Cl_2 of $0.10/lb, the chemical cost expression for Cl_2 becomes:

$$Cl_2 \text{ COST (\$/yr)} = 3878.9 \text{ (DOSE)} \tag{15}$$

where DOSE = disinfectant dosage, mg/l

Assuming a cost of $0.50/lb for ClO_2 the cost equation becomes:

$$ClO_2 \text{ COST (\$/yr)} = 19394.5 \text{ (DOSE)} \tag{16}$$

The cost equations were used to optimize facilities costs for a selected set of operating conditions. These operating conditions included the treatment rate, values of TKN and BOD_5, and the desired bacterial kill. Facilities costs were calculated for different detention times and disinfectant dosages and the minimum cost was determined along with optimum GT, dose, G, and D.T. values. In all of the optimization analyses, the treatment rate was fixed at 1041 m^3/day (275 mgd), which is the design rate of proposed wet-weather facilities for Rochester. An evaluation of facilities costs for three different quality conditions was performed using the cost optimization program. This was done for both Cl_2 and ClO_2. Minimum-cost facilities were developed for 3, 4, 5, and 6 log reductions of F. Coliforms. Comparisons were conducted employing wastewater quality representative of settled CSO, filtered CSO, and carbon adsorption effluent. Comparisons of the minimum total costs for the optimum Cl_2 and ClO_2 systems under these conditions are presented in Tables 30, 31, and 32. In most instances, the ClO_2 optimum systems exhibited lower detention times and GT values than the Cl_2 systems. However, because of the higher chemical costs associated with ClO_2, all of the Cl_2 optimum systems exhibited much lower total system costs than the ClO_2 systems. This apparently indicates that even in a high-rate application, utilization of Cl_2 instead of ClO_2 as the disinfectant will produce a more cost-effective disinfection facility.

Examples of two cost optimizations are shown in Figure 52 illustrating the trends obtained during the iteration procedure for determining the optimum cost system.

It is noted that attainment of high-rate disinfection employs chlorine dosages slightly higher than those normally encountered in conventional disinfection. It is recognized that such effluents may require dechlorination to protect receiving water aquatic life. The cost of these facilities has not been included in this analysis.

CHLORINE/CHLORINE DIOXIDE COMBINATIONS

Several tests were conducted during the Rochester studies to investigate two-stage disinfection with both Cl_2 and ClO_2. It has been suggested (42) that Cl_2 added 15 to 30 seconds prior to the addition of ClO_2, enhances disinfection. It was hypothesized that after the ClO_2 has been oxidized to ClO_2^-, any free Cl_2 also present might oxidize ClO_2^- back to ClO_2. It was further suggested (42) that this process may prolong the existence of the more potent disinfectant, ClO_2, and thus enhance disinfection beyond that expected by the sum of the respective concentrations of Cl_2 and ClO_2.

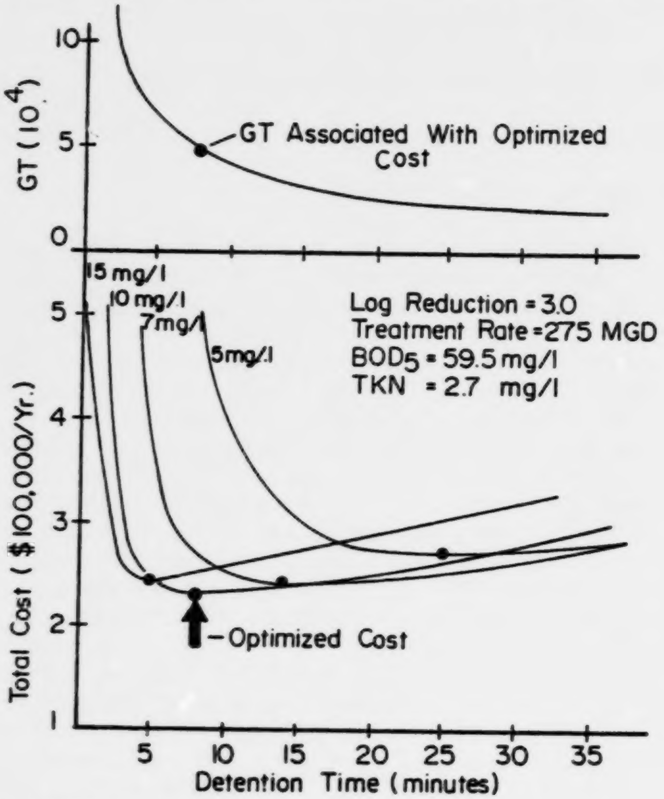


FIGURE 52. Optimization Trends

Storm No. 69 involved a series of tests on dry-weather flow comparing the disinfection performance of chlorine, chlorine dioxide, and various combinations of the two. These tests were conducted with Cl_2 added before ClO_2 and employed corrugated baffles. The results of the above tests are presented in Figures 53, 54, and 55. Figure 53 shows bacterial kill as a function of Cl_2 and ClO_2 doses for a 5.6 minute contact time. Iso-kill lines are interpolated between the observed data. This presentation indicates that ClO_2 causes the same bacterial kill as chlorine at roughly half the dosage. The fact that the iso-kill lines are nearly linear indicates that combination treatment does not exhibit a synergistic effect; combination treatment simply results in replacing a portion of one disinfectant with another.

Figures 54 and 55 represent the same test conditions but at contact times of 3.8 and 1.9 minutes. Again, the iso-kill lines are nearly linear. The slopes of the iso-kill lines presented in Figures 54 and 55 are greater, demonstrating that the contact time is less critical with ClO_2 than with Cl_2.

TABLE 30. COST OPTIMIZATION. CSO-PRIMARY EFFLUENT*

	Required Log Kill			
	3.0	4.0	5.0	6.0
Treatment With Chlorine Dioxide				
Minimum Cost ($/yr)	481,000	673,000	875,000	1,086,000
Optimum GT	26,400	48,800	63,400	86,400
Optimum Dose (mg/l)	12.0	17.8	24.1	31.0
Optimum D.T. (min)	4.0	7.0	11.0	15.0
Optimum G (sec^{-1})	110	102	96	96
Treatment With Chlorine				
Minimum Cost ($/yr)	232,000	279,000	322,000	362,000
Optimum GT	47,500	62,000	75,600	89,800
Optimum Dose (mg/l)	10.0	12.4	15.3	17.8
Optimum D.T. (min)	8.0	11.0	14.0	17.0
Optimum G (sec^{-1})	99	94	90	88

* At BOD_5 = 59.5 mg/l
TKN = 2.7 mg/l
Treatment Rate = 275 mgd

TABLE 31. COST OPTIMIZATION. CSO-FILTERED EFFLUENT*

	Required Log Kill			
	3.0	4.0	5.0	6.0
Treatment with Chlorine Dioxide				
Minimum Cost ($/yr)	201,000	278,000	357,000	440,000
Optimum GT	8,500	12,200	16,300	24,500
Optimum Dose (mg/l)	4.1	6.1	8.5	10.8
Optimum D.T. (min)	1.0	2.0	2.0	3.0
Optimum G (sec^{-1})	141	102	136	136
Treatment With Chlorine				
Minimum Cost ($/yr)	169,000	203,000	234,000	263,000
Optimum GT	30,900	39,900	48,500	57,000
Optimum Dose (mg/l)	6.4	8.1	10.1	11.7
Optimum D.T. (min)	5.0	7.0	8.0	10.0
Optimum G (sec^{-1})	103	95	101	95

* At BOD_5 = 12.6 mg/l
TKN = 2.0 mg/l
Treatment Rate = 275 mgd

TABLE 32. COST OPTIMIZATION. CSO-ACTIVATED CARBON EFFLUENT*

	Required Log Kill			
	3.0	4.0	5.0	6.0
Treatment With Chlorine Dioxide				
Minimum Cost ($/yr)	168,000	230,000	295,000	363,000
Optimum GT	6,800	10,000	13,900	16,400
Optimum Dose (mg/l)	3.2	4.9	6.6	8.7
Optimum D.T. (min)	1.0	1.0	2.0	2.0
Optimum G (sec^{-1})	113	167	116	137

(continued)

TABLE 32. (continued)

	Required Log Kill			
	3.0	4.0	5.0	6.0
Treatment With Chlorine				
Minimum Cost ($/yr)	159,000	190,000	219,000	245,000
Optimum GT	28,300	36,000	43,700	52,400
Optimum Dose (mg/l)	6.0	7.5	9.3	10.6
Optimum D.T. (min)	4.0	6.0	7.0	9.0
Optimum G (ec^{-1})	118	100	104	97

* At BOD_5 = 2.5 mg/l
TKN = 2.0 mg/l
Treatment Rate = 275 mgd

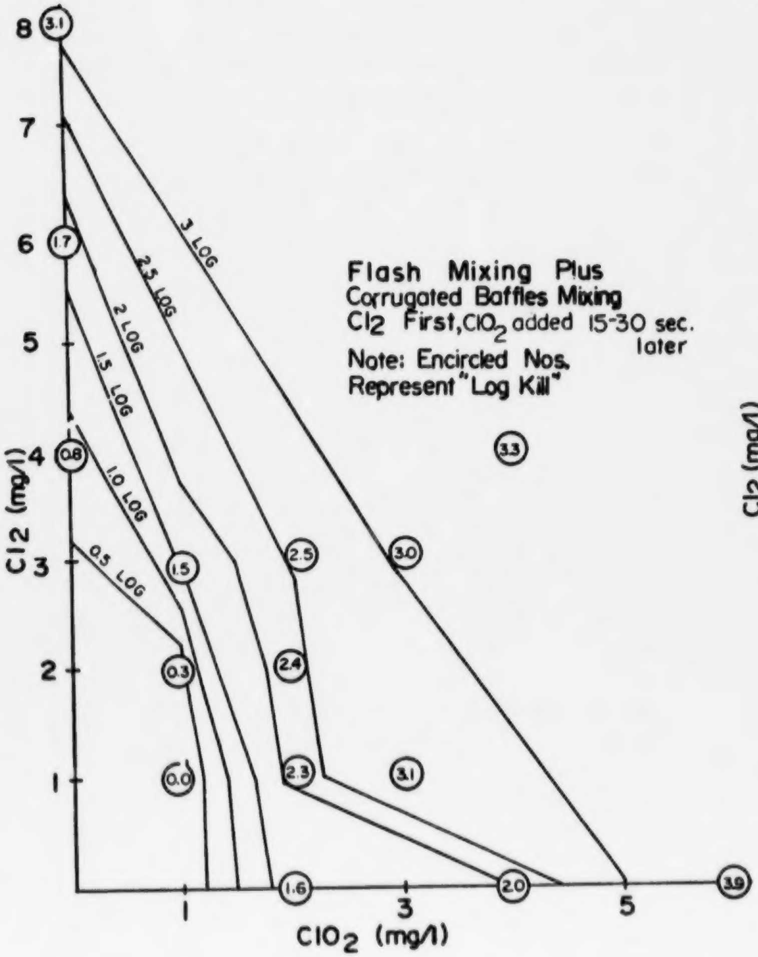


FIGURE 53. Two Stage Disinfection Iso-Kill Curves. Storm No. 69. Swirl Separator Effluent, D.T. In Disinfection Basin - 5.6 minutes

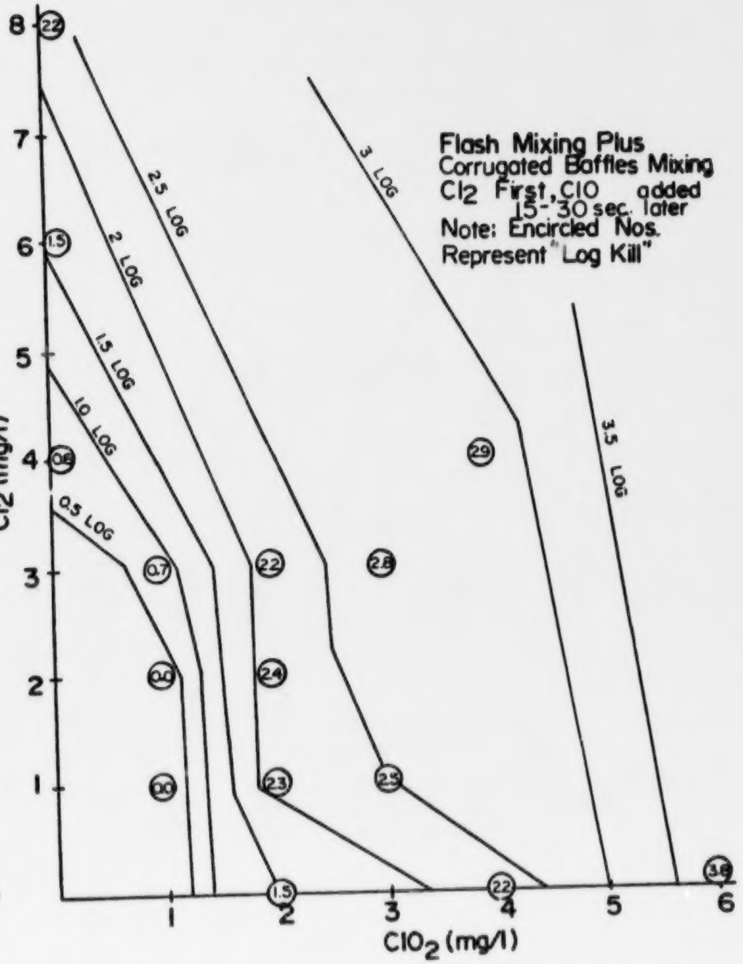


FIGURE 54. Two Stage Disinfection Iso-Kill Curves. Storm No. 69. Swirl Separator Effluent, D.T. In Disinfection Basin = 3.8 minutes

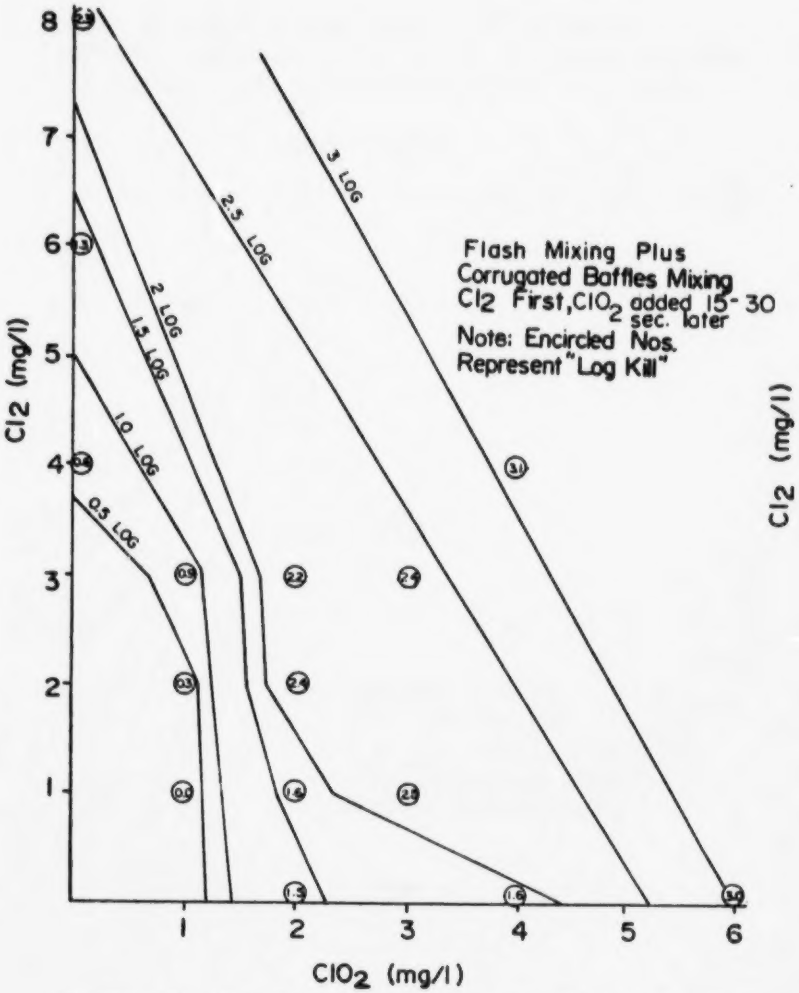


FIGURE 55. Two Stage Disinfection Iso-Kill Curves. Storm No. 69. Swirl Separator Effluent. D.T. in Disinfection Basin = 1.9 minutes.

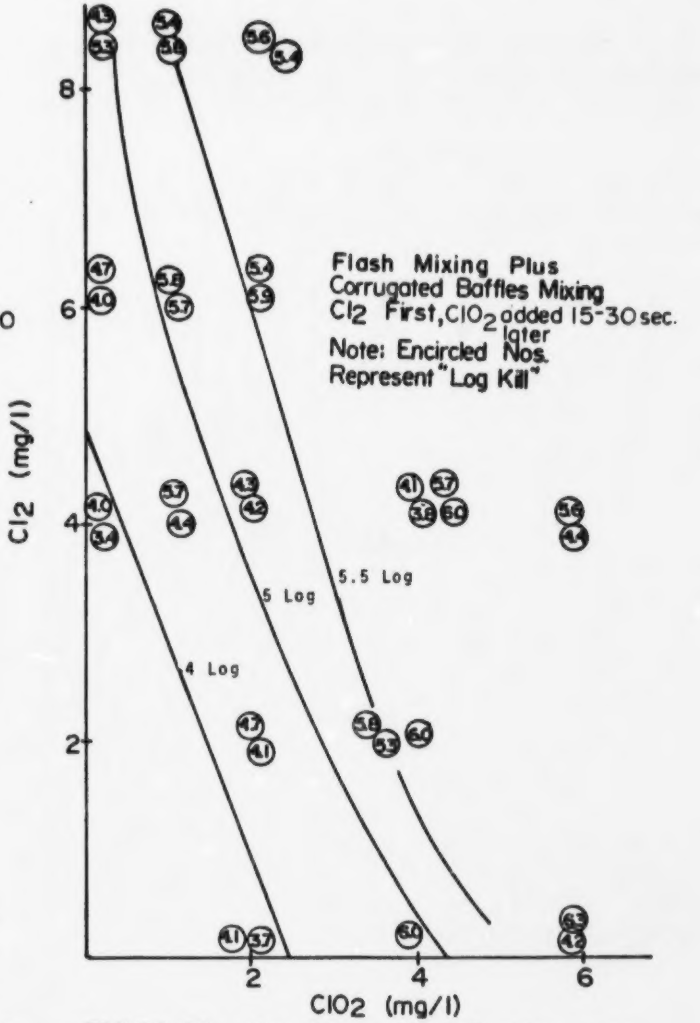


FIGURE 56. Two Stage Disinfection Iso-Kill Curves. Storm No. 17. DMHRF Effluent. D.T. in Disinfection Basin = 5.6 minutes.

Disinfection tests similar to those conducted during storm No. 69 were also performed for Storm No. 17. The results of these investigations are presented in Figures 56, 57 and 58. Again, a series of iso-kill lines were interpolated between the observed data. A comparison of these results with those obtained for Storm No. 69 reveals that similar trends were exhibited in both cases. The linear relations again illustrate no apparent synergistic effect on the combination treatment. Similar bacterial kills were again experienced with approximately half as much ClO_2 as Cl_2.

The effects of mixing and order of addition on two-stage disinfection were examined during Storms No. 19, 69 and 70. Figures 59 and 60 show the results obtained when these investigations were conducted on dry-weather flow (Storms No. 69 and 70). Wet-weather (Storm No. 17) results are presented in Figures 61, 62 and 63. Both series of tests implied that slightly higher bacterial kills are obtained when ClO_2 is introduced prior to the addition of Cl_2. Examination of the results also disclosed that in the majority of the tests, sequential flash mixing was more effective in reducing bacterial populations than were the other two mixing conditions (corrugated baffles and single flash).

A comparison of Figures 59, 60, 62 and 63 revealed that, at similar dosage combinations, greater bacterial reductions were achieved during the wet-weather investigations.

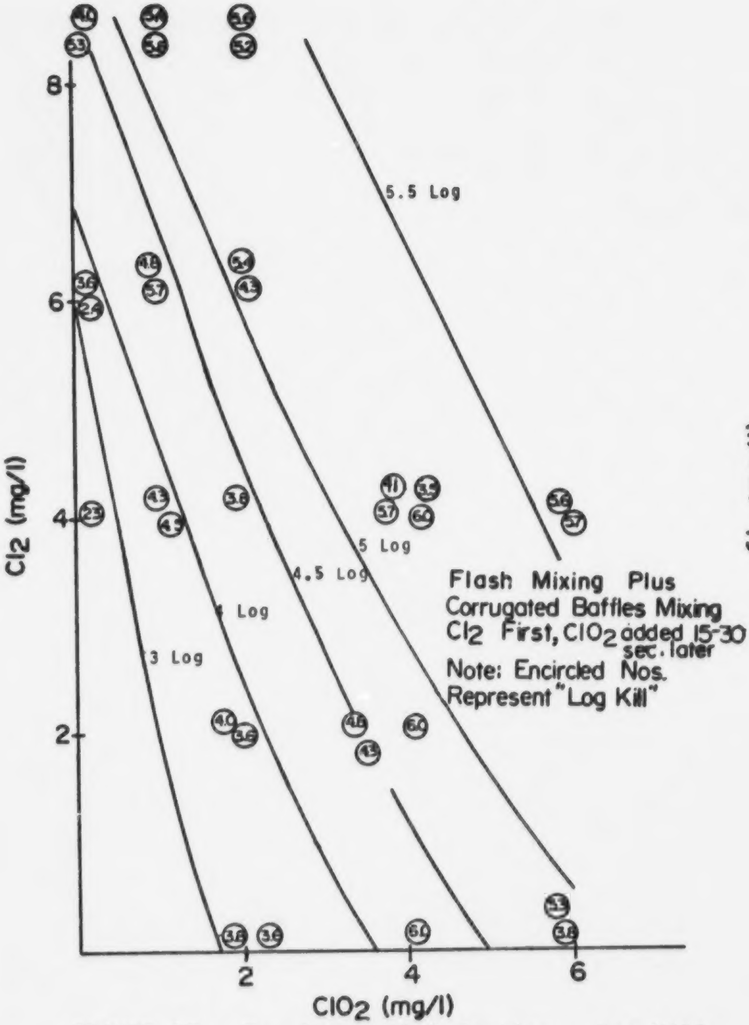


FIGURE 57. Two Stage Disinfection Iso-Kill Curves. Storm No. 17. DMHRF Effluent. D.T. In Disinfection Basin = 3.8 minutes

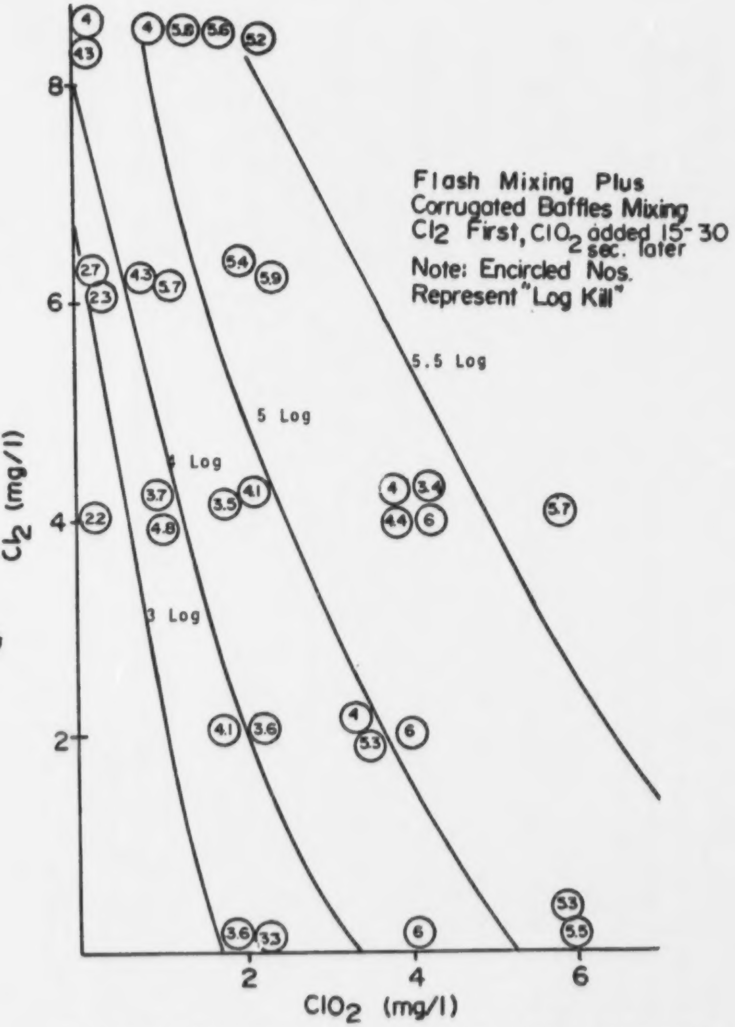


FIGURE 58. Two Stage Disinfection Iso-Kill Curves. Storm No. 17. DMHRF Effluent. D.T. In Disinfection Basin = 1.9 minutes

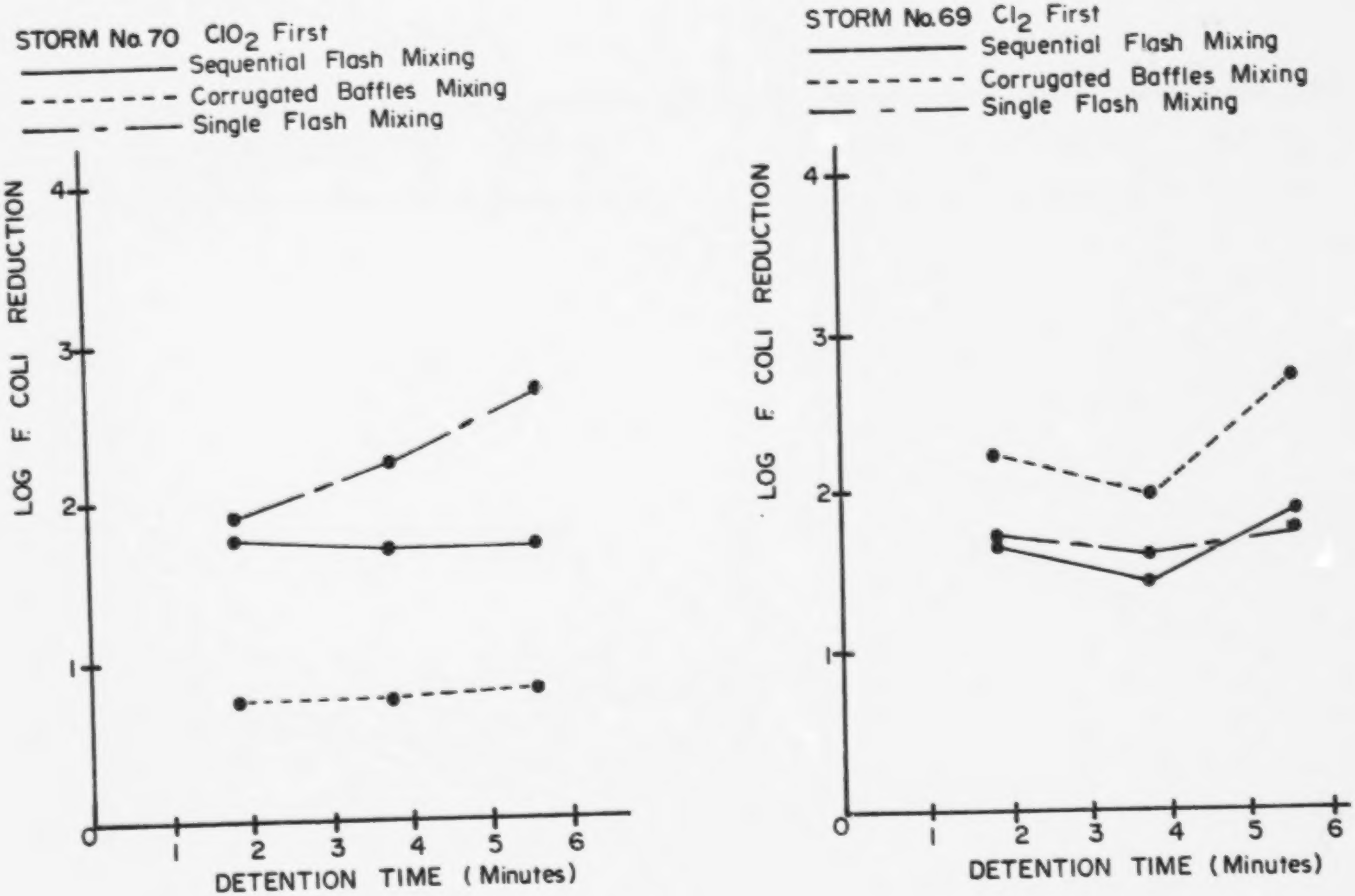


FIGURE 59. Comparisons of Order of Addition Cl_2 - ClO_2 Combinations. ClO_2 = 2 mg/l; Cl_2 = 2 mg/l

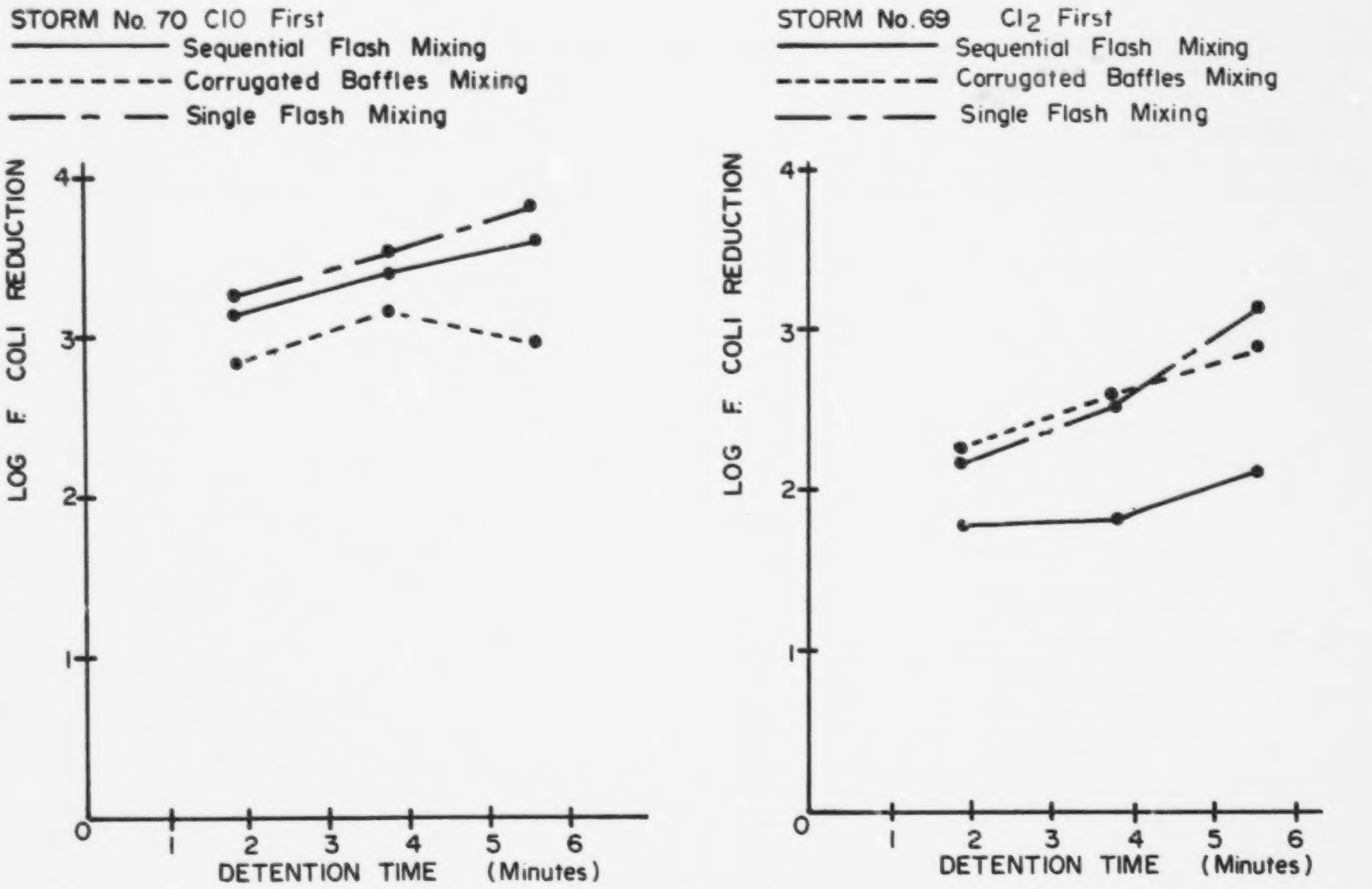


FIGURE 60. Comparison of Order of Addition Cl_2. - ClO_2 Combinations. ClO_2 = 3 mg/l; Cl_2 = 3 mg/l

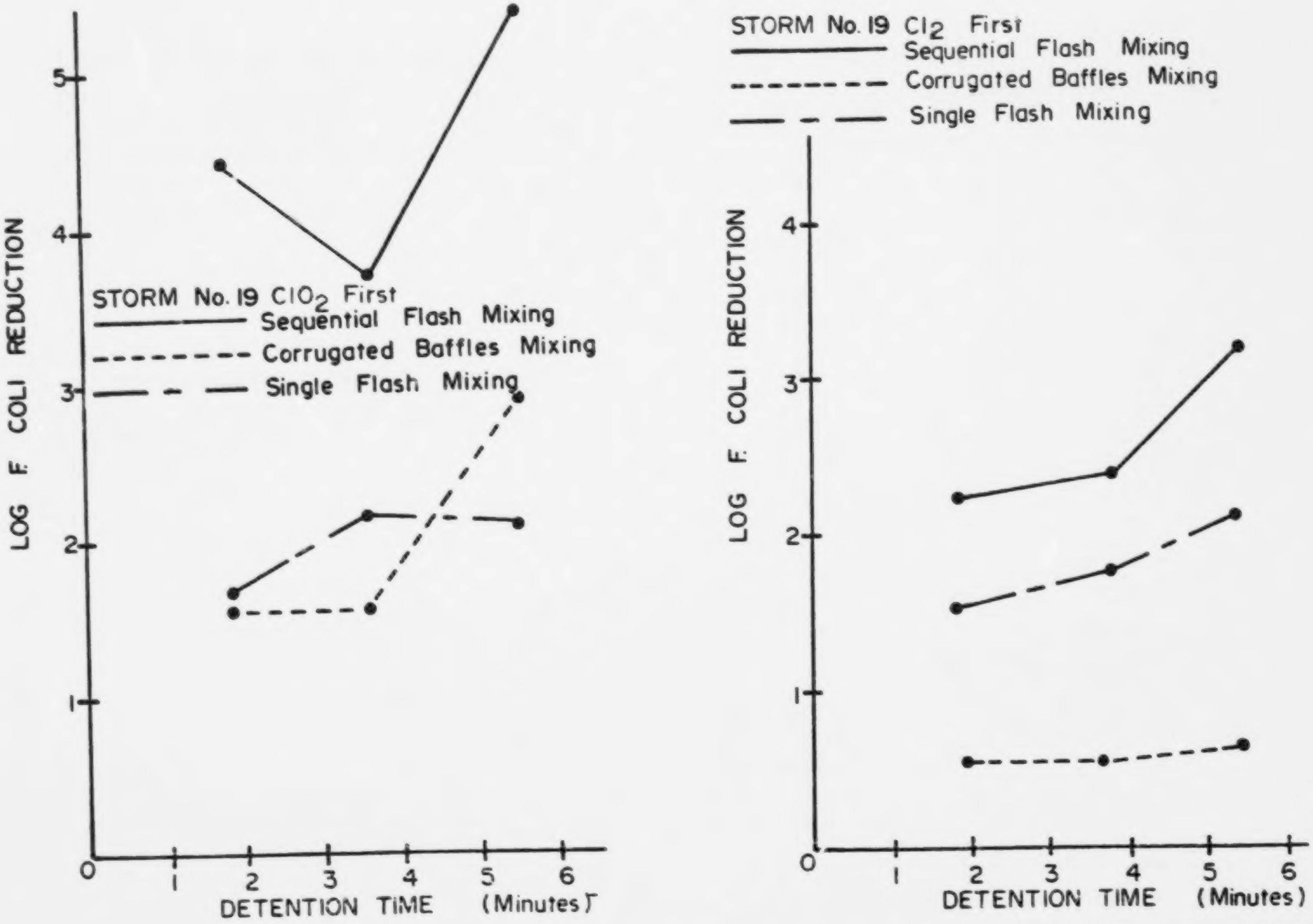


FIGURE 61. Comparison of Order of Addition Cl_2 - ClO_2 Combinations. ClO_2 = 1 mg/l; Cl_2 = 1 mg/l

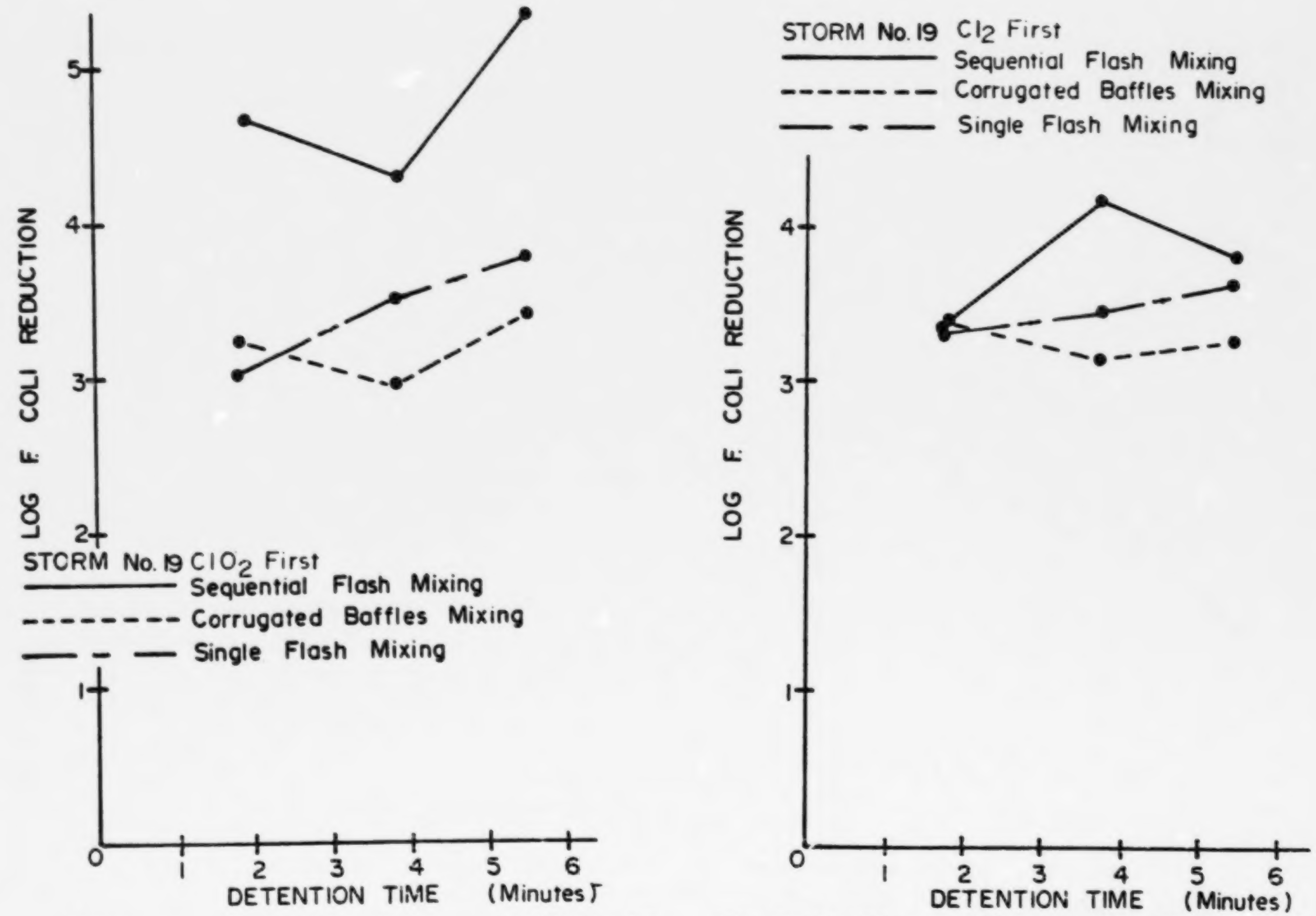


FIGURE 62. Comparison of Order of Addition Cl_2 - ClO_2 Combinations. ClO_2 = 2 mg/l; Cl_2 = 2 mg/l

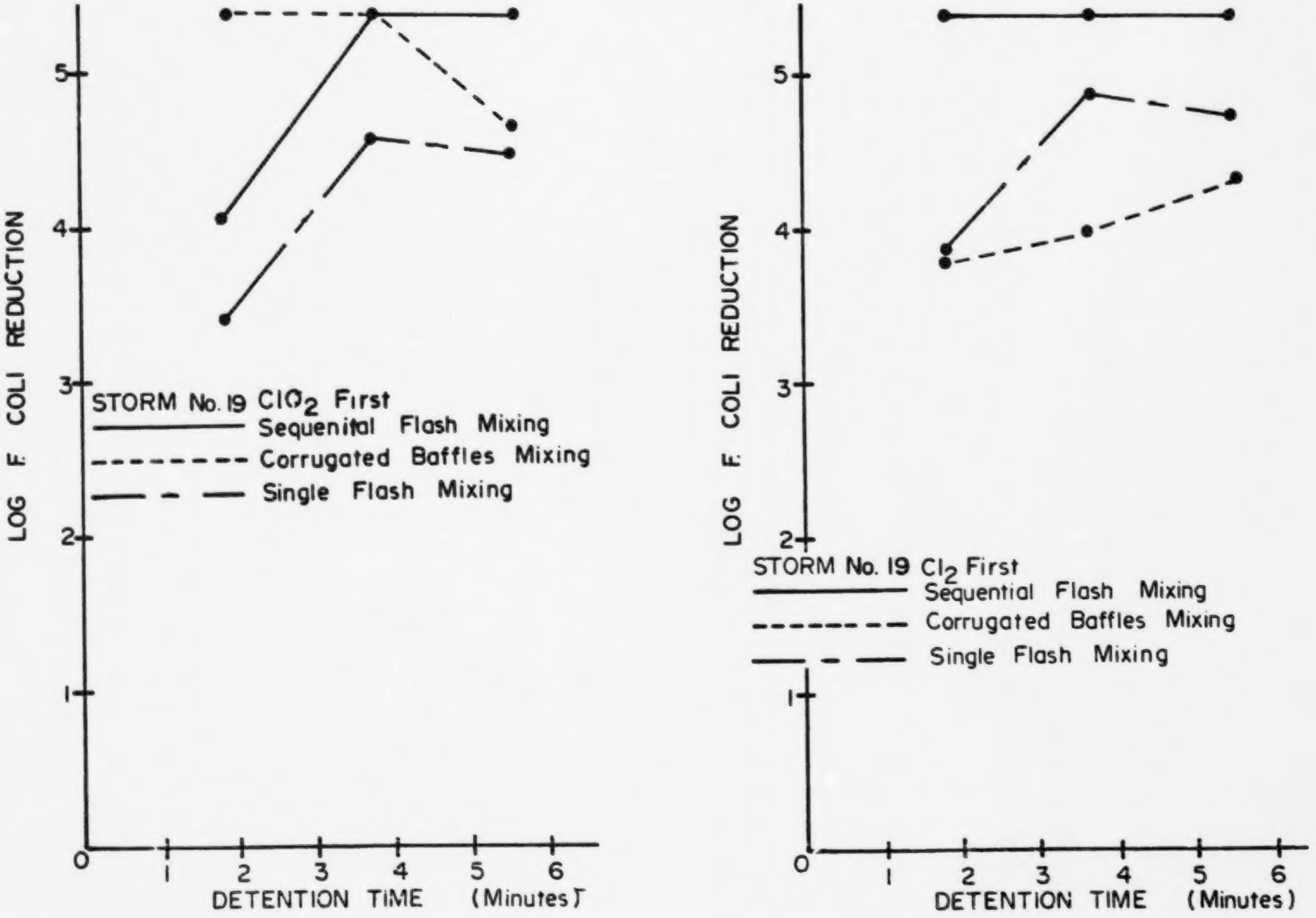


FIGURE 63. Comparison of Order of Addition Cl_2 - ClO_2 Combinations. ClO_2 = 3 mg/l; Cl_2 = 3 mg/l

SECTION 12

SOLIDS HANDLING CONSIDERATIONS

SLUDGE THICKENING

The scope of the pilot plant investigations did not permit extensive studies of optimization of sludge withdrawal rates from the primary systems. The philosophy of operation of the swirl devices was to withdraw sludges at a rate sufficiently high to prevent solids contamination of the effluent. Sludge withdrawal techniques associated with the swirl devices have been described earlier in Section 7. Rough approximations of the effect of reduced draw-off rates may be gained by analysis of sludge settleability curves, assuming that compaction would be attained in the hopper of the swirl separator. Figure 64 shows sludge settleability curves for the three primary treatment systems composite sludges acquired during Storm No. 13. These tests represent measurements of the compacting sludge layer in a 1000 ml graduated cylinder with quiescent settling.

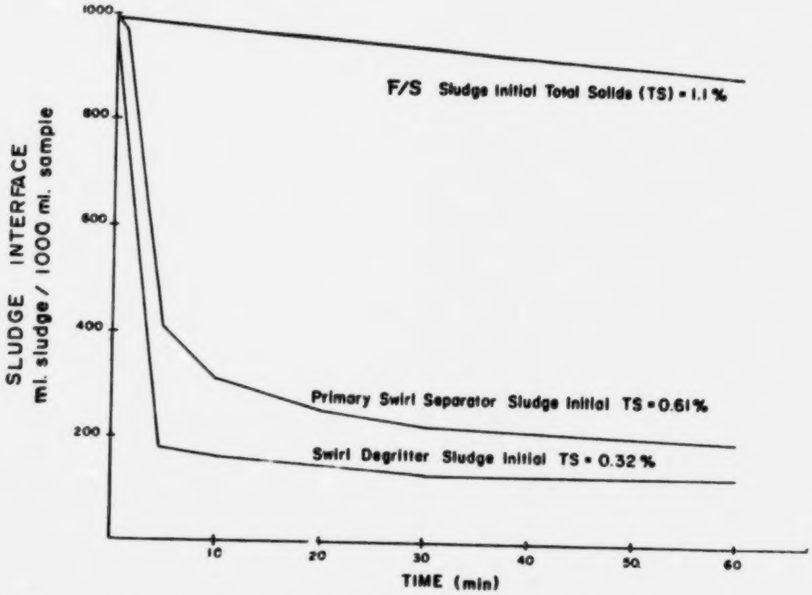


FIGURE 64. CSO Primary Treatment Sludge Settling Curves (Storm No. 13)

SLUDGE DEWATERABILITY

Dewaterability of CSO treatment residuals was also evaluated utilizing sludge derived from the pilot plant primary treatment systems. Figures 65 and 66 show results of Buchner filtration tests of flocculation/sedimentation (F/S) sludge for Storm Nos. 13 and 14, respectively. These sludges were gravity thickened to 3.28 percent total solids (TS) (Storm No. 13) and 9.32 percent TS (Storm No. 14) prior to testing. A cationic polymer (Hercules 812) was used for flocculation. These Figures also show specific resistance (a measure of dewaterability, sec^2/g) as a function of polymer dosage. Comparison of Figures 65 and 66 indicates that sludges derived from sedimentation basins employing polymer treatment exhibit a lower specific resistance than sludges originating from untreated sedimentation systems. These Figures also indicate that polymer treated sedimentation sludge is more conducive to dewatering than untreated sedimentation sludge.

Figures 67 and 68 illustrate Buchner filtration test results for combined swirl degritter and swirl primary separator sludge from Storms No. 13 and 14, respectively. Examination of the results indicates that polymer treated swirl sludge dewaters much more easily than untreated swirl sludge.

The chemical requirement for dewaterability of the sludge may be affected by its septicity. Figures 69, 70 and 71 show the changes in pH and alkalinity of pilot plant sludges upon storage at room temperature.

DISCUSSION

Sludge Volume and Characteristics

Table 33 gives a preliminary estimate of the quantity of sludge solids produced in Rochester, N.Y. during 1975 (assuming the average CSO discharge per storm).

This analysis assumes 100 percent treatment of the CSO and includes grit, sludge and scum loadings. It should be noted that utilization of biological treatment methods and/or the employment of chemical addition in the selected treatment process would also add solids to the final sludge volume.

TABLE 33. ESTIMATED LOADINGS FOR 100% CSO TREATMENT

No.	Description	Quantity
I	Average CSO per storm	3.2×10^5 m^3 (85 mil gal)
II	Average SS concentration of CSO	244 mg/l
III	Average O&G concentration of CSO	47 mg/l
IV	Estimated volume of screenings in CSO (wet basis)	$>15 ml/m^3$ (>2 ft^3/mil gal)

cont. on pg. 128

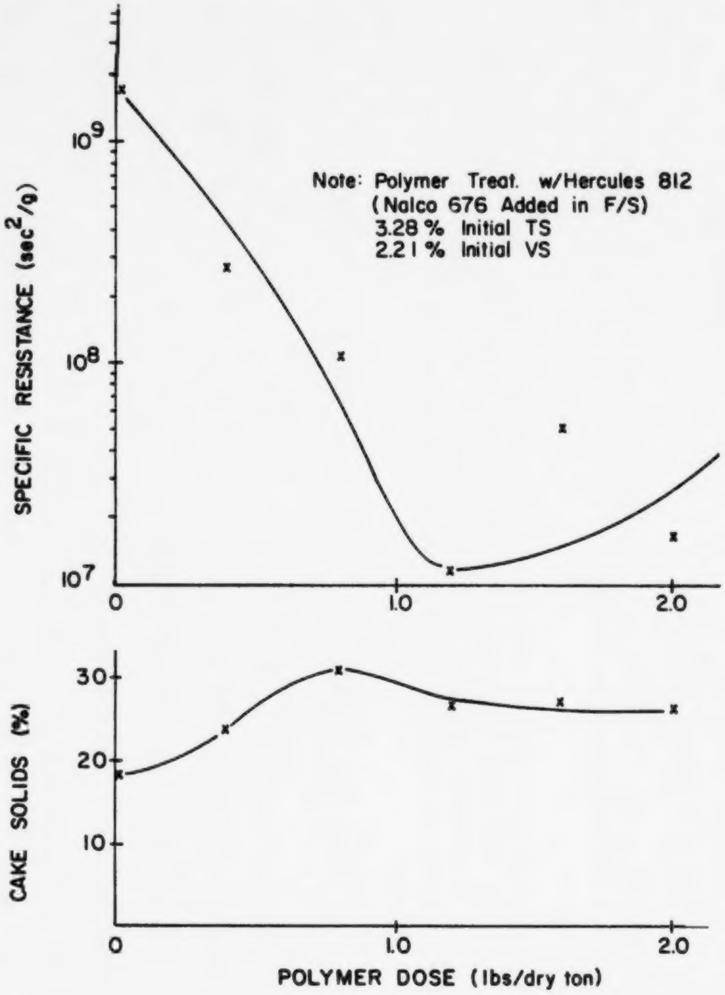


FIGURE 65. Sludge Dewaterability Tests: Storm No. 13 F/S Sludge

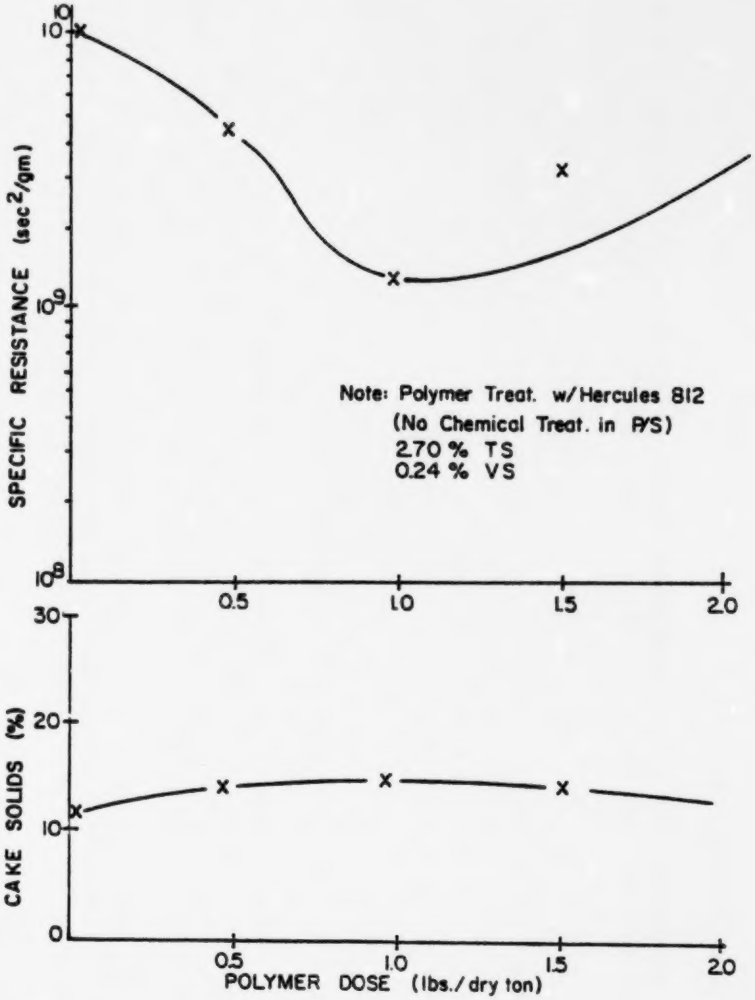


FIGURE 66. Sludge Dewaterability Tests: Storm No. 14 Swirl Degritter and Separator Sludges

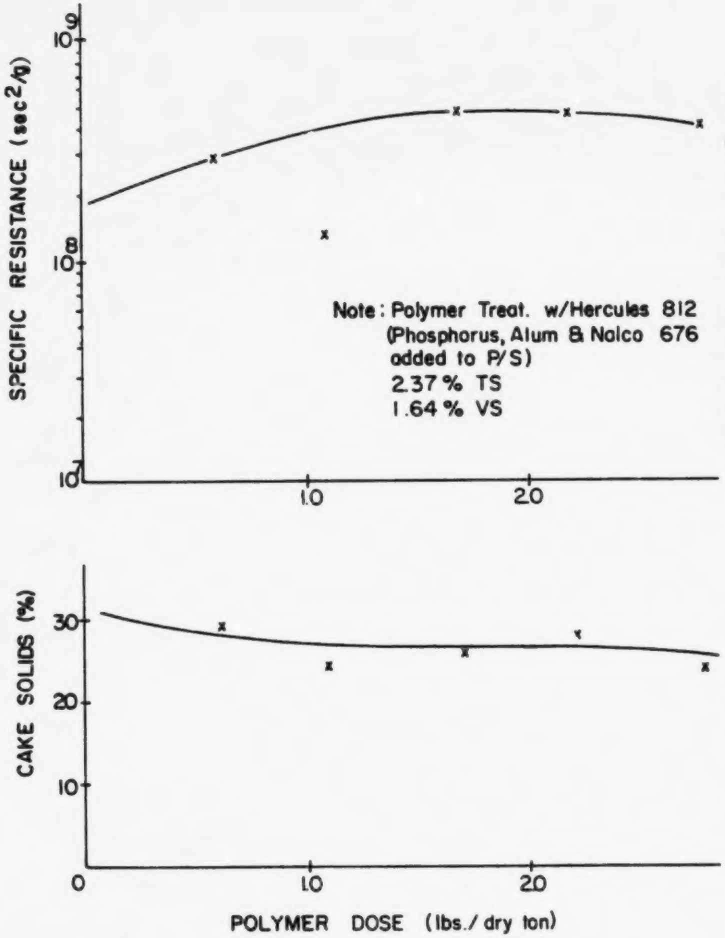


FIGURE 67. Sludge Dewaterability Tests: Storm No. 14 Swirl Degritter and Separator Sludges

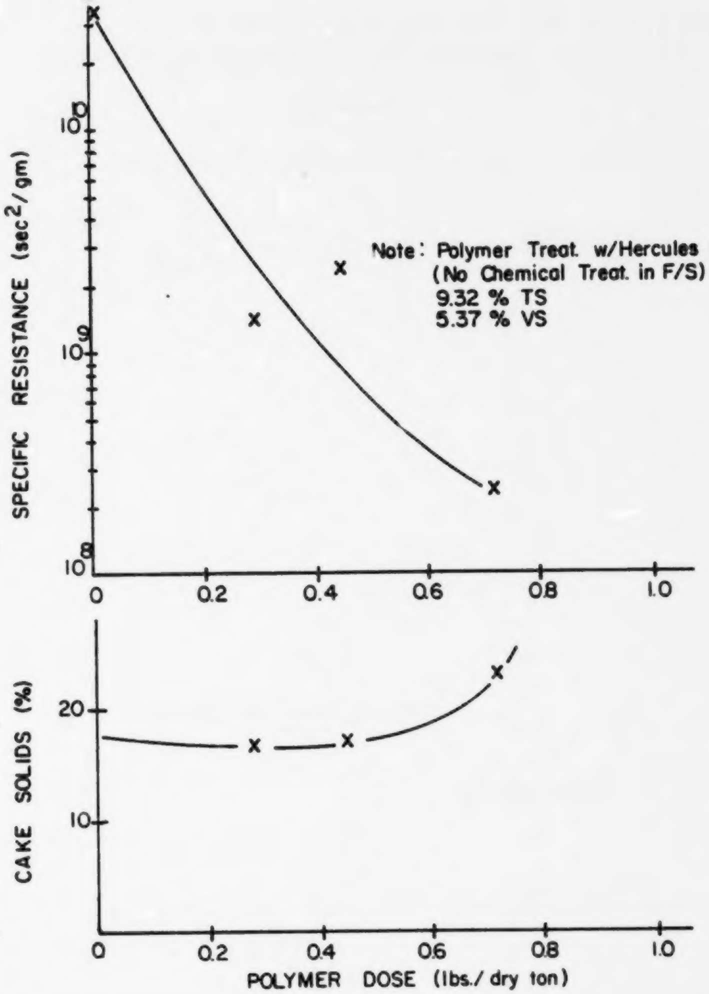


FIGURE 68. Sludge Dewaterability Tests: Storm No. 13 F/S Sludge

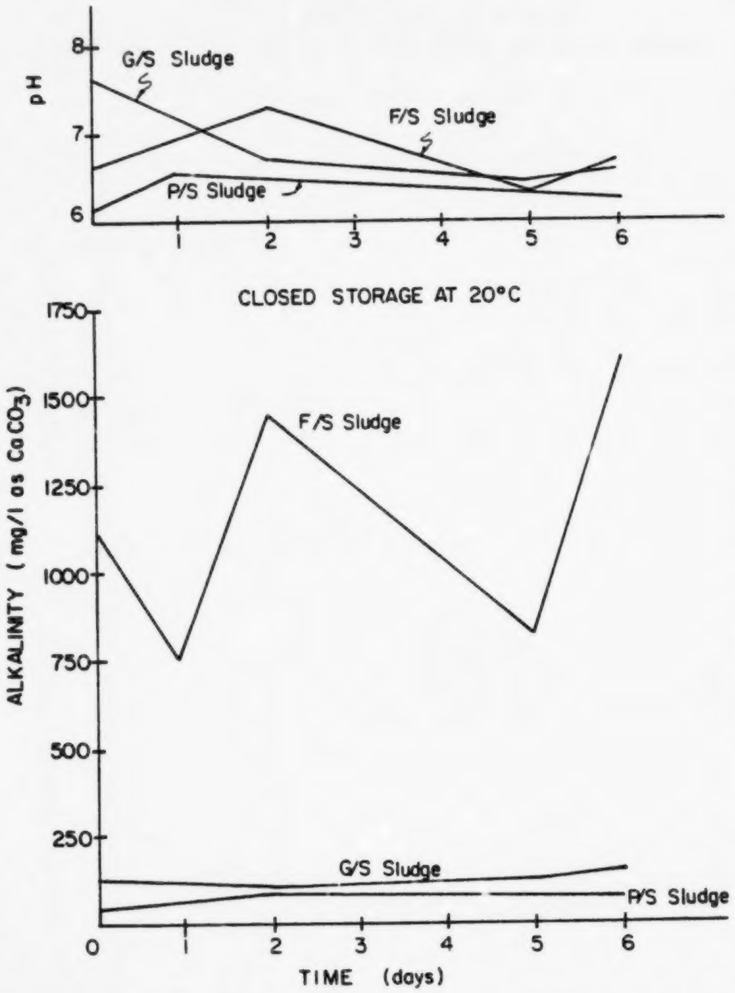


FIGURE 69. Sludge Aging Studies: Storm No. 14 F/S Sludge

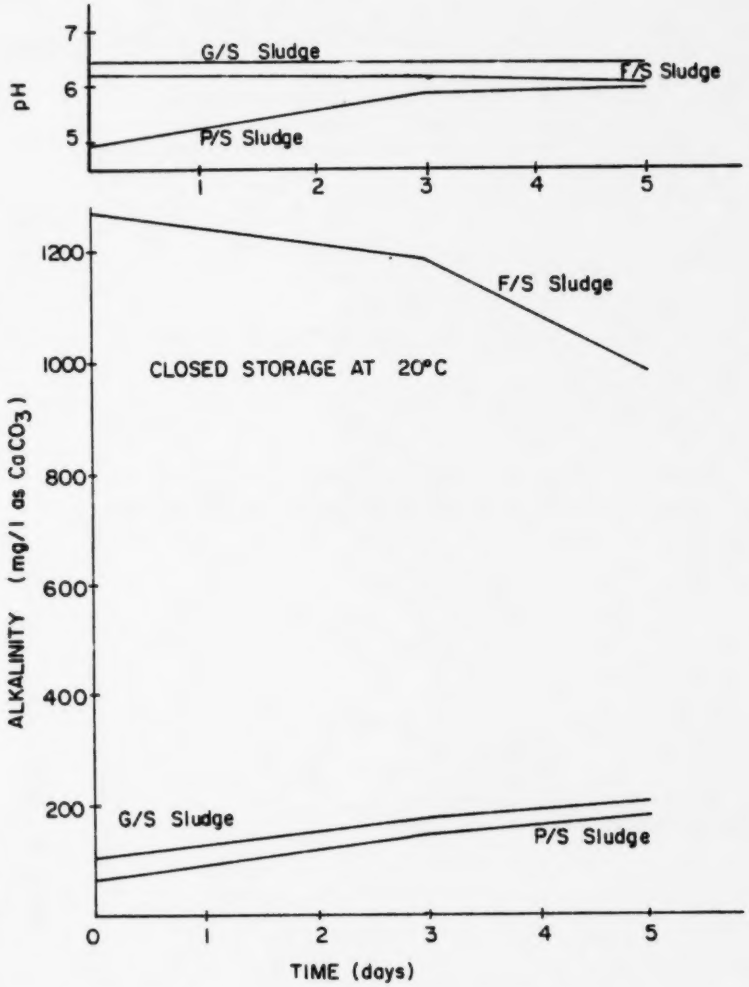


FIGURE 70. Sludge Aging Studies: Storm No. 13 Swirl Degritter and Separator Sludges

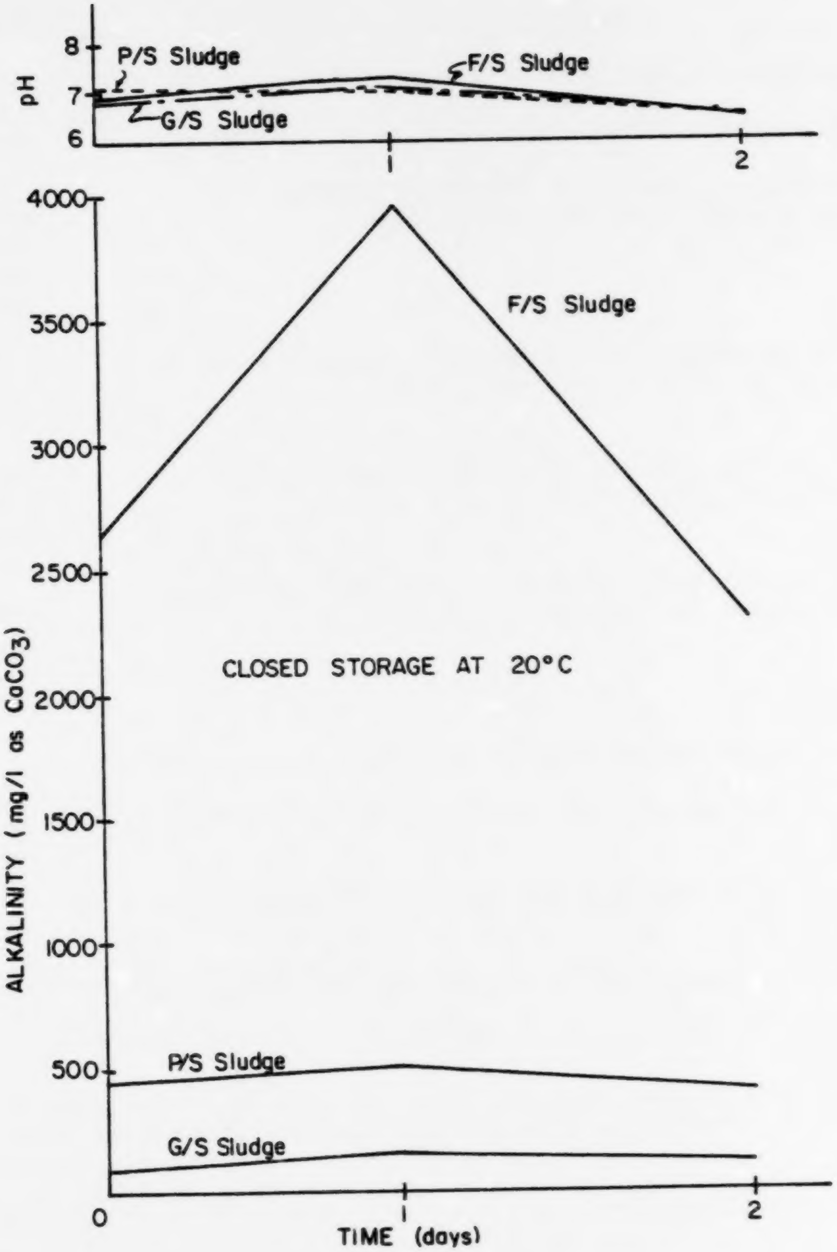


FIGURE 71. Sludge Aging Studies. Storm No. 15

TABLE 33. (continued)

No.	Description	Quantity
V	Estimated quantity of grit expressed as % of SS	9%-15.5%
VI	Average No. of overflows anticipated per year	43
VII	Estimated quantity of sludge anticipated from an average storm (dry solids basis)	42,600-48,000 kg (94,000 - 106,000 lb)
VIII	Estimated quantity of O&G anticipated from an average storm (dry solids basis)	3,800 kg (8,400 lb)
IX	Estimated quantity of screenings anticipated from an average storm	4.76 m^3 (>170 ft^3)
X	Estimated quantity of grit anticipated from an average storm (dry solids basis)	6,985 - 12,250 kg (15,400 - 27,000 lb)
XI	Estimated current VanLare operation	
	(A) Sludge processed per day (dry solids basis)	38,900 kg (85,700 lb)
	(B) Grit processed per day (dry solids basis)	7,500 kg (16,600 lb)
	(C) Screenings processed per day (wet solids basis)	4,600 kg (10,200 lb)

The volatile percentage of solids found in the flocculation/sedimentation system, swirl degritter and swirl primary separator sludges and the pilot plant influent are listed in Table 34. The pilot plant sludges averaged between 20 and 60 percent volatile solids. Envirex (55) reported sludges exhibiting volatile fractions ranging from 25 to 63 percent; biological treatment showed the highest volatile fraction (about 60 percent), while the physical and physical/chemical treatment processes exhibited sludges with a 25 to 48 percent volatile fraction. The volatile percentages of solids found in the pilot plant sludges were similar to the volatile percentage of SS in Rochester CSO (Table 8).

TABLE 34. ROCHESTER PILOT PLANT VOLATILE SOLIDS FRACTIONS

Storm No.	Influent % Vol.	F/S* Sludge % Vol.	Swirl Degritter Sludge % Vol.	P/S** Sludge % Vol.
1	18.9			
3	42.8	70.6	49.4	
4	55.9	31.8		
5	44.2	72.4	61.5	63.5
6	56.8		50.4	83.0
7A	60.3		48.0	13.0
7B	62.4	69.9	31.8	8.2
8	55.9		37.8	16.6
9	52.4	46.6	44.2	28.8
10	43.9	42.2	52.5	32.0
11	50.1	40.8	39.8	24.8
12	54.9	41.1	31.8	10.3
13	67.6	67.0	61.8	49.3
14	40.4	52.7	48.4	40.8
15	36.1		53.8	46.2
16	34.9	26.6	39.5	32.2
17	48.7	65.2	70.8	50.6
18	48.8		63.8	42.2
19	22.4		31.0	32.0

* F/S - Flocculation/Sedimentation
** P/S - Swirl Primary Separator

Possible toxic substances in CSO sludges include heavy metals (zinc, lead, copper, nickel, chromium, and mercury), PCB and pesticides (pp' DDD, pp' DDT, and dieldrin). A list of the heavy metals encountered in the pilot plant influent and the process effluents, which could contribute to the heavy metal content in the process sludges, is presented in Table 35. Another heavy metals analysis was performed on both the swirl degritter and swirl primary separator sludges for Storm No. 17. The results of this analysis are presented in Table 36. Also shown in Table 36 are the ranges of heavy metals reported in the Envirex (55) study for sludges associated with physical and physical/chemical treatment systems.

TABLE 35. PILOT PLANT CSO HEAVY METALS DATA*

	Cd mg/l	Cr mg/l	Cu mg/l	Hg ug/l	Ni mg/l	Pb mg/l	Zn mg/l
Storm No. 8							
Influent		0.03	0.05				0.07
Storm No. 9							
G/S Effluent	0.02	<.01	0.04		<.02	<.02	
P/S Effluent	<.01	<.01	0.06	0.59	0.03	0.00	0.17
P/S Effluent	<.01	<.01	0.04		<.02	<.02	
DMHRF Effluent	<.01	<.01	0.04	<.01	0.03	<.02	0.11

(continued)

TABLE 35. (continued)

	Cd mg/l	Cr mg/l	Cu mg/l	Hg ug/l	Ni mg/l	Pb mg/l	Zn mg/l
Storm No. 10							
Influent	<.01	<.01	0.04		<.02	<.02	
F/S Effluent	<.01	<.01	0.04		<.02	<.02	
G/S Effluent	<.01	<.01	0.04		<.02	<.02	
P/S Effluent	<.01	<.01	0.02		<.02	<.02	
Storm No. 11							
Influent	<.01	<.01	<.01	1.48	<.02	<.02	
P/S Effluent	<.01	<.01	<.01	0.79	<.02	<.02	
DMF Effluent	<.01	<.01	<.01	0.39	<.02	<.02	
Storm No. 17							
First Half Influent	<.01	<.01	<.01	24.2	<.02	<.02	0.07
Second Half Influent	<.01	<.01	<.02	28.0	<.02	<.02	0.11
F/S Effluent	<.01	<.01	0.06	20.2	<.02	<.02	0.15
G/S Effluent	<.01	<.01	0.08	28.9	0.03	<.02	0.12
P/S Effluent	<.01	<.01	0.06	23.1	<.02	<.02	0.13
M/S Effluent	<.01	<.01	0.06	20.7	<.02	<.02	0.10

* G/S - Swirl Degritter
P/S - Swirl Primary Separator
F/S - Flocculation Sedimentation
M/S - Micro Screen
DMHRF - Dual-Media High-Rate Filter

TABLE 36. HEAVY METAL CHARACTERISTICS OF CSO SLUDGES*

Description	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Storm No. 17 Swirl Degritter Sludge	23.4	249.6	1235	0.78	147.4	1241	2345
Storm No. 17 Swirl Primary Separator Sludge	15.8	386.1	4554	0.28	85.6	1658	1980
Physical Treatment Processes†		50- 250	200-800	0.01-3.0	125-300	1200-2500	800-1200
Physical/Chemical Processes§		150-1700	250-500	2.0 -4.0	50-225	150-1600	700-1700

(continued)

* Results reported as mg/kg of Dry Solids

† Taken from Envirex Report (55); processes included storage-sedimentation and microscreening

§ Taken from Envirex Report (55); processes included screening/dissolved-air flotation and dissolved-air flotation.

Summary of Envirex Study

CSO sludge characteristics vary as the influent solids concentrations vary. It was thus necessary to assess alternatives which may prove useful in the handling of storm generated discharge residuals. These alternatives included (1) bleed-back of the residuals to the dry-weather treatment facilities, (2) separate on-site residuals treatment and (3) land disposal of treated or untreated CSO residuals.

The following presents a summary of conclusions developed in the Envirex study (55). These conclusions are general and are not universally applicable. Site factors specific to Rochester are discussed later.

I. Effect of Handling CSO Treatment Residuals by Bleed-Back to the Municipal Dry-Weather Plant --

Investigations have indicated that bleed-back of raw CSO treatment sludges to the municipal dry-weather plant is not practical.

The Envirex report generally indicated that bleed-back of CSO treatment sludges to the dry-weather treatment plant over a 24-hour period would grossly overload the plant hydraulically, solids-wise and/or organically, resulting in appreciably decreased treatment efficiency and deterioration of the plant effluent quality.

Extending the bleed-back period does not appear to be a viable alternative. Even under favorable conditions(minimum design dry-weather plant operating conditions, no diurnal dry-weather flow flucuations, etc), a bleed-back period of up to one to two weeks or more would be required. For less than favorable conditions (plant operating conditions between minimum and maximum design operating conditions, significant dry-weather flow fluctuations, etc), a bleed-back period greater than that indicated under favorable conditions would be required. If the dry-weather plant were operating at maximum design operating conditions, no bleed-back would be allowable. Disadvantages of prolonged bleed-back periods include: (1) the longer the bleed-back period is extended, the more unfavorable the alternative becomes, (2) the capability of handling succeeding CSO treatment residual events is materially reduced and (3) because of the anticipated extended bleed-back period, provision would have to be made during sludge storage to minimize organic solids decomposition and prevent nuisance conditions from occurring.

Bleed-back of CSO treatment sludges directly to the dry-weather sludge handling facilities over a 24 hour period would hydraulically overload the facilities, both solids-wise and organically. These overloads would be expected to detrimentally affect the dewatering and stabilization performance and treatment efficiency of the dry-weather sludge handling facilities. The downgrading in treatment efficiency would be manifested in poorly stabilized sludge for disposal and grossly deteriorated thickener effluents, filtrates, supernatants, etc. for recirculation back to the dry-weather treatment plant.

Since handling of CSO treatment sludges in the dry-weather sludge handling facilities does not appear to be feasible, it becomes apparent that CSO sludge must be separately treated. Two alternatives for separate treatment are (1) on-site facilities and/or (2) additional parallel facilities at the dry-weather plant.

Biological CSO treatment facilities should be located at sewage treatment facilities to provide a continuous active biomass. Therefore, CSO sludges originating from biological treatment should be separately handled in separate parallel facilities at the dry-weather treatment plant.

Physical and physical-chemical CSO treatment facilities lend themselves more easily to remote satellite locations. However, because of the problems involved in transporting the sludges from the remote CSO treatment site to the dry-weather plant, CSO sludges derived from these systems should be separately treated at on-site facilities.

II. Effect of Handling CSO Treatment Residuals by Separate On-Site Treatment--

A. Generally, the process elements comprising a CSO sludge handling system would include grit and low volatile solids removal, sludge dewatering, stabilization and ultimate disposal. The specific sludge treatment train utilized will be dependent upon the characteristics of the CSO conveyance system and the treatment method employed.

Grit and Low Volatile Solids Removal -- Physical and physical-chemical CSO treatment methods treat raw CSO with little or no preliminary treatment for inert solids removal. It is therefore expected that CSO sludges from physical and physical-chemical treatment will require provision for grit and low volatile solids removal.

Biological CSO treatment methods are usually preceded by treatment steps which remove the major portion of the grit and inert solids in the raw CSO. Therefore, it is anticipated that CSO sludges from biological treatment will not generally require provision for grit and low volatile solids removal.

Stabilization -- It is necessary to stabilize sludges before ultimate disposal in order to minimize health hazards and nuisance conditions and further reduce mass. Stabilization processes and equipment include anaerobic and aerobic digestion, heat treatment, composting and chemical treatment (chlorine oxidation and lime treatment). Preliminary examination of these alternatives indicates that anaerobic disgestion and lime stabilization are more applicable to handling CSO sludges. Evaluation and comparison of these two processes from an operating, cost, and land requirement standpoint indicate the advisibility of employing lime stabilization.

Dewatering and Volume Reduction -- Evaluation and comparison of gravity thickening, vacuum filtration, centrifugation and incineration for applicability in handling CSO sludge indicates that thickening and vacuum filtration are the dewatering methods preferred for handling CSO sludges.

Ultimate Sludge Disposal -- Evaluation and comparison of ocean dumping, drying and land disposal (by landfill, land spreading and/or land reclamation) indicates that land disposal is the most applicable to handling CSO sludges.

B. Estimation of costs for handling and disposal of CSO sludge using landspreading and landfill as the ultimate disposal alternatives indicates that although landspreading has a significantly lower initial investment, landfills have significantly lower operating costs and appreciably lower land requirements.

C. The logistics of operating and maintaining multiple CSO solids handling plants at different locations throughout a city are formidable but not insurmountable. Similar logistics would be required for multiple CSO treatment facilities from which the sludges to be handled are derived.

III. Considerations for Land Disposal Alternatives

The criteria that must be considered for any waste disposal operation are:

1) land application method to be used,
2) required preapplication treatment,
3) collection and transportation of the waste to the site,
4) suitability of the area in terms of present and future land uses in and around the site, proximity to surface waters, and sensitive environmental areas,
5) amount of land required
6) effects of climate on the disposal operation,
7) site topography, geology, and existing vegetation,
8) surface runoff control,
9) necessary storage facilities,
10) waste distribution techniques,
11) treatment efficiency and pollutional loading constraints, especially in regard to nitrogen and heavy metals,
12) possible growth of crops,
13) protection of public health, and
14) a site monitoring program.

Specific recommendations regarding some of the preceding criteria are outlined in the Envirex Report (55).

Facilities and Cost Estimates

Using the estimated sludge quantities given in Table 33 it is seen that treatment of an average storm in Rochester over a 24-hr period would produce a solids loading of 110-124 percent of the current solids loadings at the VanLare plant. Preliminary estimates were compiled to assess the order of magnitude of sludge handling facilities required for the Rochester area. These estimates are presented on Table 37. This analysis assumed that the CSO solids would be treated in a manner similar to that used for treatment of dry-weather solids at the existing VanLare plant, i.e., sludge thickening, storage, vacuum filtration, and incineration (Option A). The cost of facilities to handle these solids was found to be in the range of $4.5 million.

Implementation of the treatment train recommended by Envirex (55), which consists of gravity thickening, lime stabilization, vacuum filtration and landfill (Option B), would substantially reduce these costs by replacing the high costs associated with the incineration process with much lower landfill costs. Based on figures derived from the Envirex Report (55), it is estimated that capital costs for lime stabilization and landfilling are $96,000 and $533,000, respectively. Thus, sludge handling facilities costs would be reduced to the range of $3.3 million.

While it appears that landfilling of sludges is the least costly alternative, there are several factors which might reduce requirements for incineration. It is possible that existing incinerators at VanLare might be capable of handling wet-weather sludges if some modifications are incorporated. Detention of wet-weather sludges may permit attenuation of vacuum filter and incinerator loadings. Lime stabilization should be applied prior to detention. Inclusion of wet-weather sludges also results in a sludge mixture that contains a higher ratio of primary/secondary components. The improved dewaterability of this type of sludge may enhance operation of the existing incinerators.

The cost estimates presented here assume centralized treatment of CSO and CSO sludges. Volume I of this Report concluded that receiving water constraints preclude the use of satellite CSO treatment; therefore, costs of satellite sludge handling facilities have not been developed.

TABLE 37. SLUDGE PROCESSING FACILITIES

		Project Cost Estimate (Mid-1976)§,††	
No.	Treatment Operation	Incinerator (Option A)	Landfill (Option B)
I.	Lime Stabilization: 9,463 m^3/day (2.5 mgd) loading (1% sludge)		$ 96,000
II.	Thickeners* Design Loading: 962,200 kg (212,000 lb) dry solids/day	$1,570,000	96,000
III.	Sludge Storage Design Loading: 1,204 m^3 (318,000 gal) - 8% sludge	540,000	540,000

(continued)

TABLE 37. (continued)

No.	Treatment Operation	Project Cost Estimate (Mid-1976) Incinerator (Option A)	 Landfill (Option B)
IV.	Vacuum Filters** Design Loading: 1-in-20 yr max. 7,260 kg (16,000 lb) dry solids/ day	590,000	590,000
V.	Landfill: (5 yr: land purchase, preparation)		533,000
VI.	Sludge Incinerator† Design Loading: 1-in-20 yr max. 7,260 kg (16,000 lb) dry solids/ day	1,880,000	
	TOTAL PROJECT COST ESTIMATE:§§	$4,580,000	$3,329,000

§ No special site conditions have been factored into estimate.

†† Equipment cost estimates are based upon references (54) and (56).

* Thickener costs include structure, mechanism, associated pumps and piping.

** Vacuum Filter costs include all mechanical equipment, pumps, piping, etc. These costs also include sludge conditioning tanks and an allowance for a structure to house filter and controls.

† Sludge incinerator costs include incinerator, controls, and necessary appurtenances including air pollution controls and ash handling equipment. An allowance has also been included for a suitable structure to house the facilities.

§§ Project costs include engineering, legal and miscellaneous fees plus contingency allowance and estimated interest during construction.

SECTION 13
CAPITAL AND OPERATING COST ESTIMATES

BASIS OF COST ESTIMATES

The cost equations presented in this section have been employed to estimate capital, operating and maintenance costs for full-scale flocculation/sedimentation and swirl concentrator unit processes. These equations were developed from cost curves presented by Benjes (57), and are based on the application of the unit process to CSO. Capital costs include structural, mechanical, piping, housing, labor, contingency, electrical and instrumentation expenses. The capital costs do not include the fees associated with land and site work, engineering, legal and administrative services, fiscal concerns, and interest during construction. Operating and maintenance costs include labor, power, chemicals, miscellaneous supplies, administration costs, laboratory and sampling, and yard maintenance. All cost equations are adjusted to November, 1976 according to the ENR Construction Cost Index of 2480.

CAPITAL COSTS

The following equation for estimating sedimentation basin capital cost has been developed from reference 57.

$$\text{SED CAP COST (\$)} = 238 \quad (SA)^{0.817} \tag{1}$$

where SA = surface area, ft^2.

The equation for estimating flocculation basin capital costs was derived from the cost curve relating construction cost to basin volume and is presented below:

$$\text{FLOC CAP COST (\$)} = 1.27\ (10^6) \times (.438 \quad + (2.29)(10^{-6})(FBV)) \tag{2}$$

where FBV = flocculation basin volume, ft^3.

Employment of chemical treatment in the flocculation/sedimentation process would require additional capital cost due to the installation of chemical feed systems. Cost equations were therefore developed for both alum and polymer feed systems since these chemicals were employed during the Rochester studies. The respective capital cost equations for alum treatment and polymer treatment were as follows:

$$\text{ALUM CAP COST (\$)} = 1.127\ (10^3)\ (28.8 \ + 0.0655 \quad (ALPPH)^{1.09}) \tag{3}$$

where ALPPH = alum feed rate, lb/hr

and,

$$\text{POLY CAP COST (\$)} = 1.12\ (10^6)\ (.0081 + .0183\ (\text{POLPPH})^{.898}) \tag{4}$$

where POLPPH = polymer feed rate, lb/hr

The cost equation for estimating swirl primary separator capital cost has also been developed from reference 57 and modified by cost data from LaSalle (12). The finalized form of the swirl primary separator capital cost equation was:

$$\text{SWIRL CAP COST (\$)} = 1620\ (\text{SA})^{0.779} \tag{5}$$

where SA = surface area, ft^2

OPERATION AND MAINTENANCE COSTS

A number of operation and maintenance costs are associated with the flocculation/sedimentation and swirl concentrator processes. The equations developed for estimating these costs are presented below.

Flocculation/Sedimentation

Operating and maintenance requirements were developed for a flocculation/sedimentation system consisting of a rapid mix basin, a flocculation basin and a sedimentation basin. Estimates of operation and maintenance labor costs associated with the rapid mix basin were derived from the following equation:

$$\text{R-M LABOR (\$/yr)} = .0156\ (\text{LC})\ (\text{NOF})\ (\text{V})^{.681} \tag{6}$$

where LC = labor cost, \$/hr
NOF = number of overflow events per year
V = basin volume, ft^3
R-M = rapid mix

Rapid mix materials costs were assessed using the equation:

$$\text{R-M MATERIALS (\$/yr)} = .844\ (\text{V})^{.688} \tag{7}$$

and power costs were estimated from:

$$\text{R-M POWER (\$/yr)} = .104\ (\text{PC})\ (\text{NOF})\ (\text{V}) \tag{8}$$

where PC = power cost, \$/kwh

The above equation was developed assuming two days of operation per overflow event.

Flocculation basin operating and maintenance labor costs were obtained from the following equation:

$$\text{FLOC LABOR (\$/yr)} = .000375\ (LC)\ (NOF)\ (V) \qquad (9)$$

Material and supply costs for the flocculation basin were calculated using:

$$\text{FLOC MATERIALS (\$/yr)} = 1.99\ (V)^{.588} \qquad (10)$$

Operating and maintenance costs associated with the sedimentation basin were derived from:

$$\text{SED LABOR (\$/yr)} = 0.0211\ (LC)\ (NOF)\ (SA)^{.875} \qquad (11)$$

where SA = surface area of basin, ft^2

and materials costs were computed from:

$$\text{SED MATERIALS (\$/yr)} = 8114\ (SA/112500)^{0.7} \qquad (12)$$

Sedimentation basin power requirements were estimated from:

$$\text{SED POWER (\$/yr)} = .0042\ (PC)\ (NOF)\ (SA)^{.926} \qquad (13)$$

Employing chemical treatment in the flocculation/sedimentation process would also contribute to its operating and maintenance costs. Listed below are the equations which were developed for estimating these costs for both the alum and polymer feed systems.

1) Manpower Requirements

$$\text{ALUM FEED LABOR (\$/yr)} = .0452\ (LC)(NOF)(ALPPH)^{.715} \qquad (14)$$

$$\text{POLY FEED LABOR (\$/yr)} = 2.94\ (LC)(NOF)(POLPPH)^{.167} \qquad (15)$$

2) Materials and Supplies:

$$\text{ALUM FEED MATERIALS (\$/yr)} = 1.12\ (47.5 + .914\ (ALPPH)) \qquad (16)$$

$$\text{POLY FEED MATERIALS (\$/yr)} = 1.12\ (69.6 + 69.5\ (POLPPH)) \qquad (17)$$

3) Requirements (assumes two days of operation per overflow event):

$$\text{ALUM FEED POWER (\$/yr)} = (NOF)\ (PC)\ (12.2 + .00676(ALPPH)) \qquad (18)$$

$$\text{POLY FEED POWER (\$/yr)} = (NOF)\ (PC)(7.52 + 4.05\ (POLPPH)) \qquad (19)$$

4) Chemicals:

$$\text{ALUM FEED CHEMICALS (\$/yr)} = 8.34\ (MGTPY)(DOSE)(CC) \qquad (20)$$

$$\text{POLY FEED CHEMICALS (\$/yr)} = 8.34\ (MGTPY)(DOSE)(CC) \qquad (21)$$

where MGTPY = million gallons treated per year
DOSE = chemical dose, mg/l
CC = chemical cost, $/lb

Swirl Concentrator

The cost equation developed for estimating swirl concentrator labor costs was:

$$\text{SWIRL LABOR (\$/yr)} = (LC)(NOF)(12.1 + .0082\,(SA)) \qquad (22)$$

Estimates of materials and supply costs for the swirl concentrator were computed from the following equation:

$$\text{SWIRL MATERIALS (\$/yr)} = 2028\ (NUMUNITS)^{0.7} \qquad (23)$$

where NUMUNITS = number of swirl units

Miscellaneous Costs

Presented below is a list of equations which were developed to estimate additional operating and maintenance costs which would generally accompany any type of combined sewer overflow treatment facility.

1) Administration and general manpower:

$$\text{A \& G LABOR (\$/yr)} = 20\ (LC)(Q)^{.460} \qquad (24)$$

where Q = treated flow, mgd

2) Administration and general materials and supplies:

$$\text{A \& G MATERIALS (\$/yr)} = 84.5\ (Q)^{.470} \qquad (25)$$

3) Laboratory manpower (assumes 2 days of lab. work per overflow event):

$$\text{LAB LABOR (\$/yr)} = 17.4\ (LC)\ (NOF) \qquad (26)$$

4) Laboratory materials and supplies (assumes 2 days of lab. work per overflow event and 4 samples/day):

$$\text{LAB MATERIALS (\$/yr)} = 51.8\ (NOF) \qquad (27)$$

5) Yardwork manpower (assumes yardwork area equal to 2.5 times the equipment surface area):

$$\text{YARD LABOR (\$/yr)} = 26.7\ (LC)\ (SA/400)^{.795} \qquad (27)$$

6) Yardwork materials and supplies:

$$\text{YARD MATERIALS (\$/yr)} = 15.4\ (SA/400)^{.862} \qquad (28)$$

Several other costs associated with CSO handling and treatment are discussed in Section 14. These include overflow storage and transmission facilities and sludge disposal costs.

SECTION 14

COMPARISON OF ALTERNATIVES

COST/BENEFIT COMPARISON OF SWIRL PRIMARY SEPARATOR VERSUS FLOCCULATION/SEDIMENTATION

Cost/benefit comparisons of four alternative primary systems for treating CSO are presented below. These include: 1) flocculation/sedimentation with no chemical treatment, 2) flocculation/sedimentation with polyelectrolyte treatment, 3) flocculation/sedimentation with alum and polyelectrolyte treatment, and 4) swirl primary separator with no chemical treatment. All costs were adjusted to November, 1976 based on the ENR Construction Cost Index of 2480. Comparisons of satellite versus centralized treatment, and storage versus treatment optimizations are presented in Volume I of this Report (3).

Performance equations defined percent SS removal at various hydraulic loadings and influent SS concentration. However, the designs associated with each hydraulic loading result in facilities with different capital costs. The operation and maintenance costs associated with each system are also different. For example, treatment with chemicals in the flocculation/sedimentation system results in improved performance but also results in higher operating and maintenance costs. It was the intent of the cost/benefit analysis to compare the cost and performance tradeoffs resulting from variations in-system design and operating conditions. Several design configurations were selected for each primary system and capital costs and predicted performance were developed for each design condition.

Operation and maintenance costs associated with each design were then calculated from the operation and maintenance equations outlined in Section 13. The following assumptions were made to develop the performance and cost data for an example facility: a) collection and attenuation of overflows with treatment at a central facility (VanLare STP in Rochester, N.Y.) and a treatment rate of 275 mgd, b) 77 overflow events per year and c) a total treated CSO volume of 4651 mil gal per year. The assumed treatment rate was based on the design rate of the proposed wet-weather facilities at VanLare. The number of overflow events and total CSO volume were based on the available Rochester data for recent years.

The costs outlined in this Section include comparison of the primary unit processes only. These costs do not include real estate nor facilities for collection, transmission and storage of CSO, pumping, flow measurement, preliminary screening, disinfection, sludge handling, treatment and disposal. It was assumed that these items and associated costs would be common to each of the primary alternatives. Disinfection and sludge handling costs have been discussed in Sections 11 and 12. Costs associated with the collection, transmission and storage of CSO and raw wastewater pumping are outlined in

Volume I of this Report (3). That Volume also presents additional treatment alternatives and cost optimizations of various CSO abatement alternatives.

Capital, operating and maintenance costs, and predicted performance results for various design conditions at two different influent SS levels were developed.

Amortization is for a period of 20 years at an interest rate of 6 percent per annum. Total yearly treatment facility costs for two influent SS conditions are plotted in Figures 72 and 73. These figures indicate the estimated cost to achieve stated performance levels using alternative systems. For example, Figure 73 indicates that for flows encountered during first-flush overflows ($c_o \sim 500$ mg/l), three of the four alternatives would be expected to provide 50 percent removal of SS at approximately the same annual cost. For influent SS concentrations more representative of average CSO conditions ($c_o \sim 300$ mg/l), Figure 72 indicates that swirl primary separators are cost-competitive with flocculation/sedimentation incorporating chemical treatment. For SS removals greater than 60 percent, the only system capable of providing this treatment appears to be a flocculation/sedimentation system employing alum and polyelectrolyte treatment.

Examination of Figures 72 and 73 also indicates that in all cases, the highest SS removals are attained utilizing a flocculation/sedimentation system employing alum and polyelectrolyte treatment. These Figures illustrate that large improvements in performance of the flocculation/sedimentation system are attained by chemical treatment for a relatively small increase in yearly cost.

SECONDARY LEVEL TREATMENT ALTERNATIVES

The addition of high-rate filters to the primary systems would result in overall SS removals of 72 to 84 percent when filters are operated without chemical treatment. Addition of high-rate filters that employ chemical treatment following the primary systems would result in overall SS removals of 86 to 92 percent. The capital cost associated with a high-rate filtration system employing polyelectrolyte treatment is estimated to be \$6,300,000. This cost is based on a design flow of 1×10^6 m^3/day (275 MDG) and a surface flux of 651 l/min m^2 (16 gpm/ft^2). The capital cost has been developed from reference 57 and includes structural, mechanical, piping, housing, labor, contingency, and electrical and instrumentation expenses.

The addition of a carbon adsorption system to the primary treatment processes would result in overall BOD_5 removals of 92 to 98 percent. Capital costs were developed for a carbon adsorption system consisting of a carbon contactor and complete regeneration facilities (41). Carbon contactor costs include carbon, miscellaneous tanks, piping, valves, building costs, and instrumentation. Regeneration costs include a feeding and conveying system, scrubber, afterburner, instrumentation storage, dewatering, defining tanks, and building costs. The capital cost associated with the carbon contactor was based on a design flow of 1 x 10^6 m^3/day (275 mgd) and a contact time of 30 minutes. Regeneration costs were developed for a furnace loading rate of 195 kg/m^2 yr (40 lb/ft^2 yr), a carbon exhaustion rate of 60 gm/m^3 (500 lb/mil gal), 77 overflow events per year and a total treated CSO volume of 17.6 x 10^6 m^3 (4651 mil gal) per year. Total capital cost of the carbon adsorption system was estimated to be $45,000,000.

MISCELLANEOUS COSTS

The capital costs associated with flow measurement and primary sludge pumping were derived from cost curves presented in reference 57. These costs include structural, mechanical, piping, housing, labor, contingency, and electrical and instrumentation costs. The flow measurement cost was based on a design flow of 1 x 10^6 m^3/day (275 mgd) and was estimated to be $64,000. Assuming a SS concentration of 209 mg/l (average SS value of Rochester pilot plant influent), a SS removal rate of 70 percent and a sludge solids concentration of 2.5 percent, the sludge pumping cost was estimated at $327,000.

Cost curves developed by Smith (59) were utilized to derive the preliminary screening capital cost. The capital cost was estimated to be $1,200,000. This cost includes a screen chamber, grit chamber (or swirl degritter), overflow, and bypass chamber.

DISCUSSION

The above anlaysis applies only to the stated case of central treatment at the the VanLare facility. Other areawide alternatives are discussed in Volume I of this Report (3). That Volume considers several alternatives including: (1) storage and treatment of the first-flush from all of the river overflow sites at wet-weather facilities located at the VanLare plant and treatment of all post first-flush flows with primary swirl devices; (2) storage and treatment of the total overflow at a treatment plant located on the Genesee River in the vicinity of the lower falls; (3) storage and treatment of the total overflow at a treatment plant located at the VanLare facility; (4) storage and treatment similar to that expressed in Alternative 1, with the exception that the post first-flush is not treated but directly discharged to the river; (5) treatment of the entire overflow volume at each of the river overflow locations using primary swirl concentrators; and (6) conveyance of the river overflows to the Cross-Irondequoit Tunnel for storage and treatment at the VanLare facility.

Optimization of storage versus treatment rates were also discussed in Volume I of this Report. That Volume concluded that since organic loadings to the Genesee River are critical, the only alternative that could be considered was collection and storage of the combined sewer overflow with treatment by facilities at the VanLare location. A storage volume of 0.2 x 10^6 m^3 (60 mil gal) was recommended with a treatment rate of 1 x 10^6 m^3/day (275 mgd) at the wet-weather facilities. In order to meet the requirement of the EPA for primary treatment with disinfection, it appears

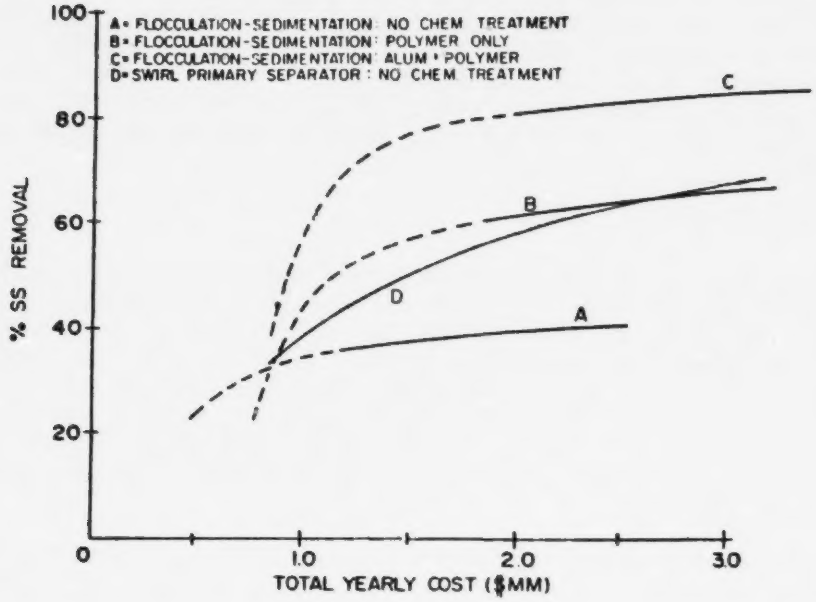


FIGURE 72. Cost-Performance Comparisons. Inf. SS=300 mg/l

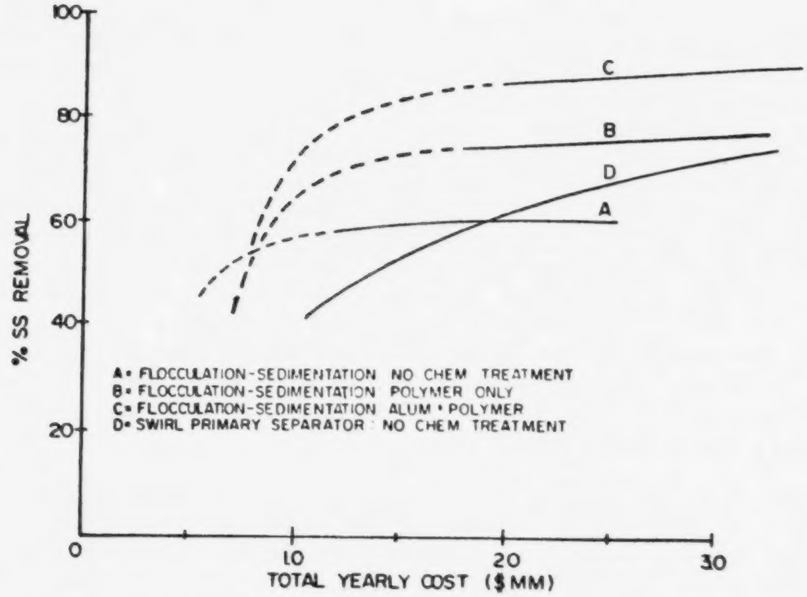


FIGURE 73. Cost-Performance Comparisons. Inf. SS=500 mg/l

that the most appropriate system would be flocculation/sedimentation operated at 82 m^3/day m^2 (2000 gpd/ft^2) with alum and polyelectrolyte treatment followed by a high-rate disinfection process employing a 5 minute detention time and a mixing intensity (GT) of 35,000. Recommended sludge handling would include thickening, lime stabilization, vacuum filtration, and landfill disposal.

The alternatives evaluated in this Section were specifically limited to swirl separators and flocculation/sedimentation with and without chemical treatment. Based on receiving water quality objectives, as discussed in Volume I of this report, the objective was to develop recommendations for primary treatment of CSO at Rochester using centralized facilities. Other alternatives, such as dissolved air flotation, microscreening, dual-media high-rate filtration, or carbon adsorption, may be viable processes for other locations, depending on effluent objectives.

REFERENCES

1. Field, R. and A.N. Tafuri. Stormflow Pollution Control in the U.S. Combined Sewer Overflow Seminar Papers. USEPA Report No. EPA-670/2-73-077, NTIS No. PB 231 836, November 1973.

2. Field, R. Combined Sewer Overflows. Civil Engineering ASCE, 43, 2 February 1973.

3. Drehwing, F.J., C.B. Murphy, D.J. Carleo, and T.A. Jordan. Combined Sewer Overflow Abatement Program, Rochester, N.Y.: Volume I, Abatement Analysis, USEPA Grant No. Y005141, November 1978.

4. O'Brien & Gere Engineers, Inc. Combined Sewer Overflow Abatement Program, Rochester, New York. Detailed Project Plan, USEPA Grant No Y005141. October 1974.

5. O'Brien & Gere Engineers, Inc. Combined Sewer Overflow Abatement Program, Rochester, New York. Detailed Project Plan Revisions, USEPA Grant No. Y005141. January 1976.

6. Hazen, A. On Sedimentation. Transactions American Society of Civil Engineers, 53, 45, 1904.

7. Camp, T.R. Studies of Sedimentation Basin Design. Sewage and Industrial Wastes, 25, 1, January 1953.

8. Dick, R.I. Folklore in Design of Final Settling Tanks. Presented at the 28th Industrial Waste Conference, Purdue University, May 1-3, 1973.

9. Theroux, R.J., and J.M. Betz. Sedimentation and Preaeration Experiments at Los Angeles. Sewage and Industrial Wastes, 31, 1259, November 1959.

10. Betz, J.M. The Valley Settling Basin Facilities, Los Angeles, California. Sewage and Industrial Wastes, 29, 667, June 1957.

11. Kalbskopf, K.H. European Practice in Sedimentation, Water Quality Improvement by Physical and Chemical Processes. University of Texas Press, Austin, Texas, 1970.

12. Sullivan, R.H., et al. The Swirl Primary Separator: Development and Pilot Demonstration. USEPA Report No. EPA-600/2-78-122, NTIS No. Pending, December 1976.

REFERENCES (continued)

13. O'Brien & Gere Engineers, Inc. Preliminary Design Additional Treatment, Frank E. VanLare Wastewater Treatment Plant. December 1973.

14. Nebolsine, R., P.J. Harvey, and C-Y Fan. High Rate Filtration of Combined Sewer Overflows. USEPA Report No. 11023 EYI 04/72, NTIS No. PB 211 144, April 1972.

15. Smisson, B. Design, Construction and Performances of Vortex Overflows. Proc., Symp. on Storm Sewage Overflows. Inst. Civil Eng., G.B. 1967.

16. Sullivan, R.H., et al. The Swirl Concentrator as a Combined Sewer Overflow Regulator Facility. USEPA Report No. EPA-R2-72-008, NTIS No. PB 214 687, September 1972.

17. Sullivan, R.H., et al. Relationship Between Diameter and Height for the Design of a Swirl Concentrator as a Combined Sewer Overflow Regulator. USEPA Report No. EPA-670/2-74-039, NTIS No. PB 234 646, June 1974.

18. Sullivan, R.H., et al. The Swirl Concentrator as a Grit Separator Device. USEPA Report No. EPA-670/2-74-026, NTIS No. PB 233 964, June 1974.

19. White, R.A. A Small Scale Swirl Concentrator for Storm Flow. Ph.D. Thesis, University of Wisconsin, Milwaukee.

20. Smisson, B. Swirl Concentrators in Combination Using Multiple Tanks (Unpublished).

21. Field, R. Design of a Combined Sewer Overflow Regulator/Concentrator. JWPCF, 46, 7, 1722, July 1974.

22. Field, R., et al. Treatability Determinations for a Prototype Swirl Combined Sewer Overflow Regulator/Solids-Separator. Proceedings of the Urban Stormwater Management Seminars, Atlanta, Georgia, November 4-6, 1975, and Denver, Colorado, December 2-4, 1975, USEPA Report No. WPD 03-76-04, NTIS No. PB 260 889, January 1976.

23. Field, R. The Dual Functioning Swirl Combined Sewer Overflow Regulator/Concentrator. Water Research, Vol. 9, Pergamon Press, 1975.

24. Sullivan, R.H., et al. The Helical Bend Combined Sewer Overflow Regulator/Concentrator. USEPA Report No. EPA-600/2-75-062, NTIS No. PB 250 619, December 1975.

25. Neketin, T.H., and H.K. Dennis. Demonstration of Rotary Screening for Combined Sewer Overflows. USEPA Report No. 11023 FDD 07/71, NTIS No. PB 206 814, July 1971.

REFERENCES (continued)

26. Glover, G.E., and G.R. Herbert. Microscreening and Disinfection of Combined Sewer Overflows - Phase II. USEPA Report No. EPA-R2-73-124, NTIS No. PB 219 879, January 1973.

27. FMC Corporation, Correspondence, June 24, 1976.

28. Maher, M.B. Microstraining and Disinfection of Combined Sewer Overflows - Phase III. USEPA Report No. EPA-670/2-74-049, NTIS No. PB 235 771, August 1974.

29. Phillips, T.G., and A.D. Bubp. The Effects of Prescreening Storm Water and Combined Sewer Overflows. Presented at the Ohio WPCF Conference, June 1975.

30. Keilbaugh, W.A., et al. Microstraining - with Ozonation or Chlorination - of Combined Sewer Overflows. Combined Sewer Overflow Seminar Papers, USEPA Report No. 11020---03/70, NTIS No. PB 199 61, November 1969.

31. Baumann, E.R., and J.Y.C. Huang. Granular Filters for Tertiary Wastewater Treatment. JWPCF, 46, 1958, August 1974.

32. Tchobanoglous, G., and R. Eliassen. Filtration of Treated Sewage Effluent. ASCE Journal SED, 96, 261, April 1970.

33. Lynam, B.T., et al. Tertiary Treatment at Metro Chicago by Means of Rapid Sand Filters and Microstrainers. JWPCF, 41, 247, February 1969.

34. Storm Water Management Model, Volume 1 - Final Report. USEPA Report No. 11024DOC07/71, NTIS No. PB 203 289, July 1971.

35. DeFilippi, John A. Assessment of Alternative Methods for Control/ Treatment of Combined Sewer Overflows. Combined Sewer Overflow Seminar Papers, USEPA Report No. 11020---03/70, NTIS No. PB 199 61 November 1969.

36. O'Brien & Gere Engineers, Inc. Nutrient Removal Using Existing Combined Sewer Overflow Treatment Facilities. Draft Report. USEPA Demonstration Grant No. S-802400, September 1976.

37. O'Brien & Gere Engineers, Inc. Nutrient Removal Using Existing Combined Sewer Overflow Treatment Facilities. Bench Scale Study for Onondaga County Department of Public Works, February 1975.

38. Cleasby, J.L., et al. Developments in Backwashing of Granular Filters. ASCE Journal EED, 101, 713, October 1975.

39. Process Design Manual for Suspended Solids Removal. USEPA Report No. EPA 625/1-75-003a, January 1975.

REFERENCES (continued)

40. Process Design Manual for Carbon Adsorption, USEPA Report No. EPA 625/1-71-002a, October 1971.

41. Fornwalt, H.J. and R.A. Hutchins. Purifying Liquids with Activated Carbon. Chemical Engineering, 73, 179, April 11, 1966.

42. Moffa, P.E., et al. Bench-Scale High-Rate Disinfection of Combined Sewer Overflows with Chlorine and Chlorine Dioxide. USEPA Report No. EPA-670/2-75-021, NTIS No. PB 242 296, April 1975.

43. Ridenour, G.M., and R.S. Ingols. Chemical Properties of ClO_2 in Water Treatment. J. Amer. Water Works Ass., 40, 1207, 1958.

44. White, G.C. Disinfection Practices in the San Francisco Bay Area. JWPCF, 46, 89, January 1974.

45. Collins, H.G., et al. Problems in Obtaining Adequate Sewage Disinfection. ASCE, Journal SED, 97, 549, October 1971.

46. Kruse, C.W., et al. The Enhancement of Viral Inactivation by Halogens. Water and Sewage Works, 118, 187, June 1971.

47. Camp, T.R., and P.C. Stein. Velocity Gradient and Internal Work in Fluid Motion. Journal of the Boston Society of Civil Engineers, 30, 219, 1943.

48. Process Design Manual for Upgrading Existing Wastewater Treatment Plants. USEPA Technology Transfer, October 1974.

49. Glover, G.E. High-Rate Disinfection of Combined Sewer Overflow. Combined Sewer Overflow Seminar Papers. USEPA Report No. EPA-670/2-73-077, November 1973.

50. Palin, A.T. Determining Chlorine Dioxide and Chlorite. J. Amer. Water Works Ass., 62, 483, August 1969.

51. Chick, H. An Investigation of the Laws of Disinfection. Journal of Hygiene, Cambridge, England, 8, 92, 1908.

52. Rich, L.G. Unit Processes of Sanitary Engineering. John Wiley and Sons, Inc., New York, 1963.

53. Sykes, G. Disinfection and Sterilization. D. VanNostrand Co., Inc., New York. 1958.

54. Culp, Wesner, Culp. Estimating the Costs of Wastewater Treatment Facilities. Draft Report for Commonwealth of Virginia, March 1974.

REFERENCES (continued)

55. Huibregtse, K.R., et al. Handling and Disposal of Sludges Arising from Combined Sewer Overflow Treatment, Phase II - Impact Assessment. USEPA Report No. EPA-600/2-77-0536, NTIS No. PB 280 309, December 1977.

56. Van Note, R.H., et al. A Guide to the Selection of Cost Effective Wastewater Treatment Systems. USEPA Report No. EPA-430/9-75-002, July 1975.

57. Benjes, H.H., Jr. Cost Estimating Manual - Combined Sewer Overflow Storage and Treatment. USEPA Report No. EPA-600/2-76-286, NTIS No. PB 266 359, December 1976.

58. Water Treatment Plant Design, American Water Works Assoc., Inc., New York, N.Y. 1969.

59. Smith, R. Cost of Conventional and Advanced Treatment of Wastewater. JWPCF, 40, 1546, September 1968.

60. Burns and Roe, Inc. Process Design Manual for Suspended Solids Removal. Technology Transfer, USEPA Report No. EPA 625/1-75-003a, January 1975.

61. Parker, H.W. Wastewater Systems Engineering. Prentice-Hall, Inc., New Jersey 1975.

62. Havens and Emerson, Ltd. Survey Scope Study for Wastewater Management Program. Cleveland, Ohio, October 1972.

63. Huber, W.C., et al. Storm Water Management Model User's Manual - Version II. USEPA Report No. EPA-670/2-75-017, March 1975.

64. Sullivan, R.H. et al. Field Prototype Demonstration of the Swirl Degritter. USEPA Report No. EPA-600-2-77-185, NTIS No. PB 272 668, September 1977.

65. Gupta, M.K. and R.W. Agnew, Screening/Dissolved-air Flotation Treatment of Combined Sewer Overflows. Combined Sewer Overflow Seminar Papers. USEPA Report No. EPA-670/2-73-077, NTIS No. PB 231 836, November 1973.

66. Parker, D.S., et al. Processing of Combined Physical-Chemical-Biological Sludge. Presented at the 46th WPCF Conference, Cleveland, Ohio, October 1973.

67. Imhoff, K. and G.M. Fair, Sewage Treatment, John Wiley and Sons, Inc., New York, 1941.

68. Keefer, G.E., Sewage Treatment Works, McGraw-Hill, New York, 1940.

REFERENCES (continued)

69. Federation of Sewage and Industrial Wastes Assns. Sewage Treatment Plant Design - Manual of Practice No. 8. 1959.

70. Great Lakes - Upper Mississippi Board of State Sanitary Engineers. Recommended Standards for Sewage Works. 1968.

71. American Society of Civil Engineers. Sewage Treatment Plant Design - Manual of Practice No. 8. 36. 1960.

72. Smith, R. Preliminary Design of Simulation of Conventional Wastewater Renovation Systems Using the Digital Computer. US EPA Report. 1968.

73. Letter of D.A. Louma, US EPA Region II, to I. Brodell, Monroe County Division of Pure Waters, dated November 3, 1972.

74. Black & Veatch Consulting Engineers. Report on Comprehensive Sewerage Study for the City of Rochester, NY, 1969.

75. Teetor-Doban Consulting Engineers. Engineering Report, Irondequoit. Bay Pure Waters District, Monroe Co., NY, December, 1968.

76. Lozier Engineers, Inc., Seelye Stevenson Value and Knecht and Erdman Anthony Associates. Wastewater Facilities Plan, Volume IV subreports, Combined Sewer Overflow Abatement Program. Rochester Pure Waters District, Monroe Co., NY, December, 1975.

77. American Public Works Association, Standard Methods for the Analysis of Water and Wastewater, Fourteenth Edition, 1975.

78. NERC, Manual of Methods for Chemical Analysis of Water and Wastes, US EPA Report No. EPA-526/6-74-003, 1974.

APPENDIX A
SS vs. Time Plots-Flocculation/Sedimentation and Swirl Concentrators

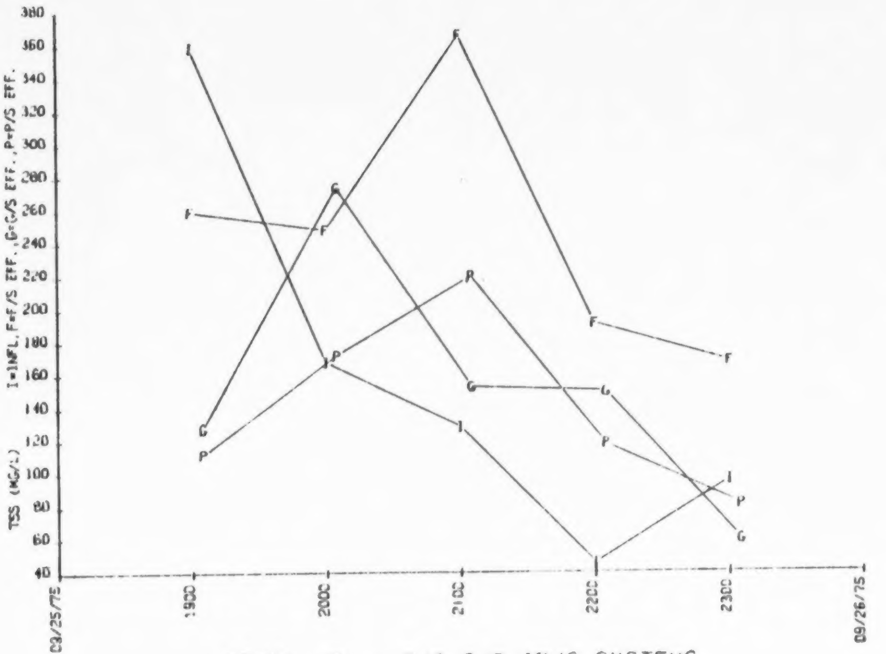
Legend

I = Influent

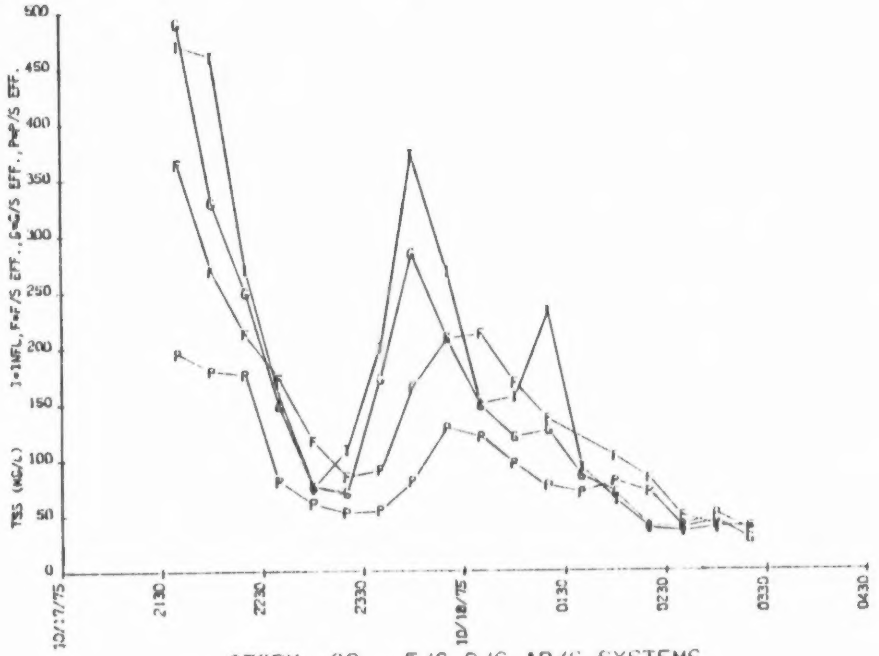
F = Flocculation/sedimentation system effluent

G = Swirl degritter effluent

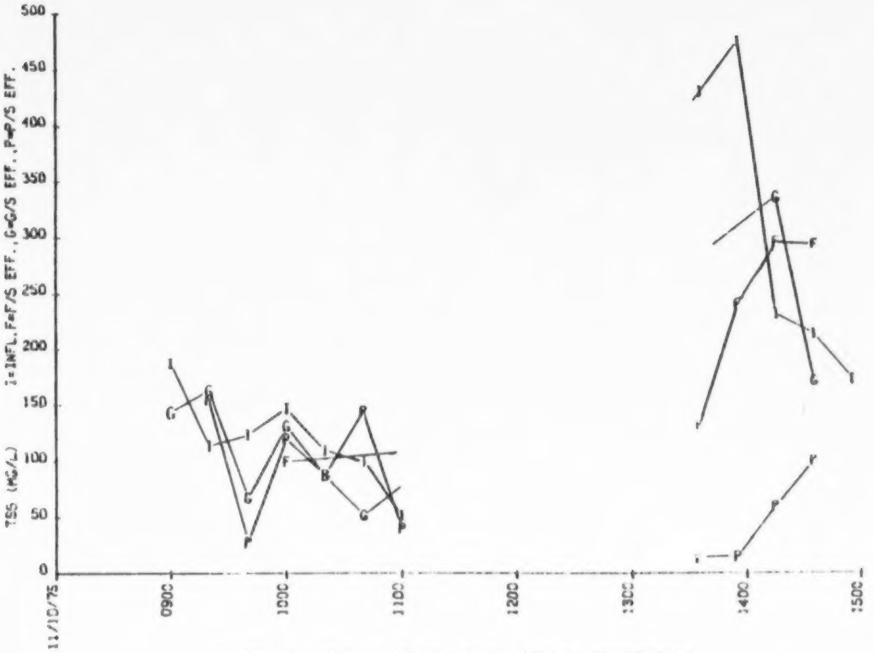
P = Swirl primary separator effluent



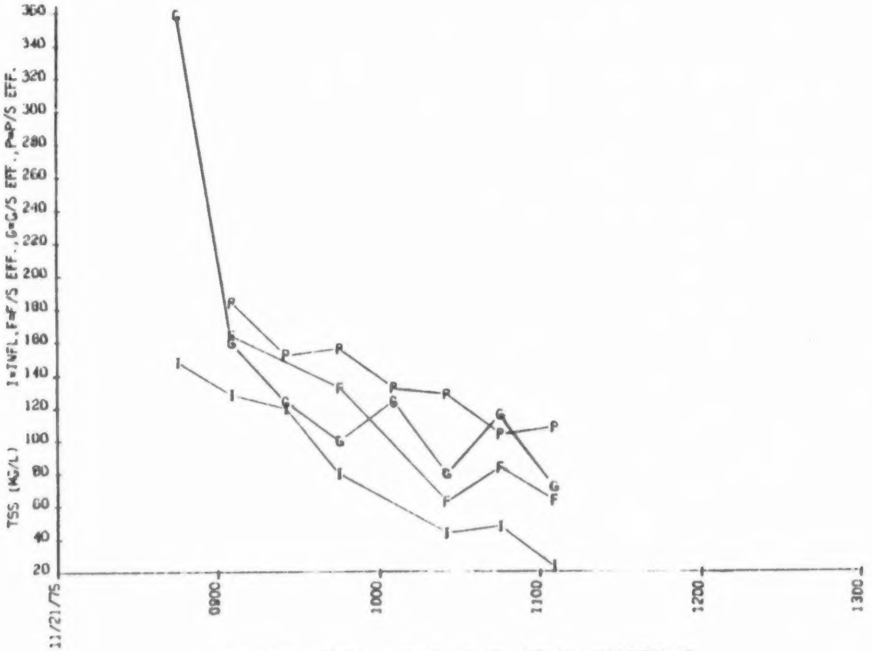
STORM #01 - F/S, G/S, &P/S SYSTEMS



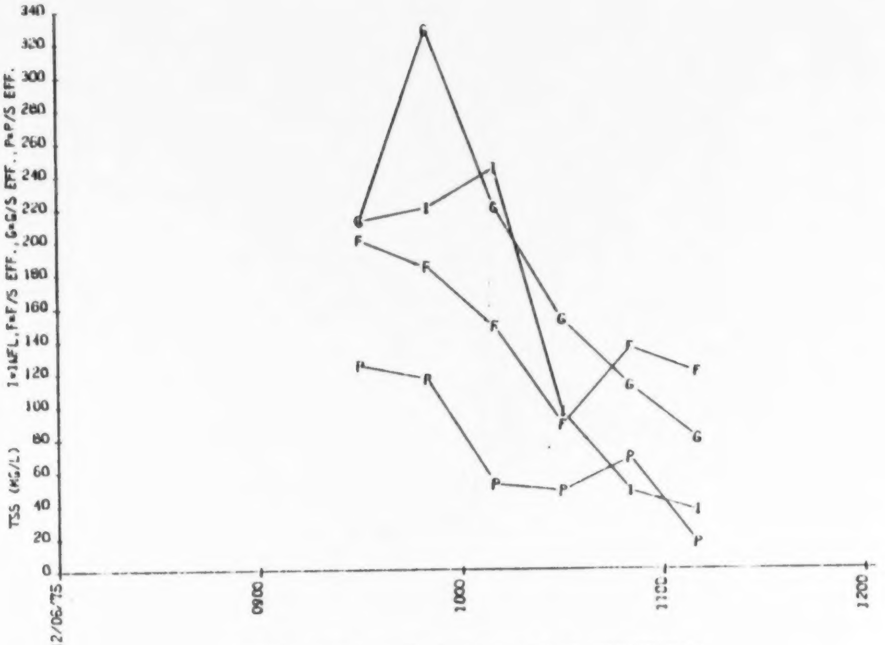
STORM #03 - F/S, G/S, &P/S SYSTEMS



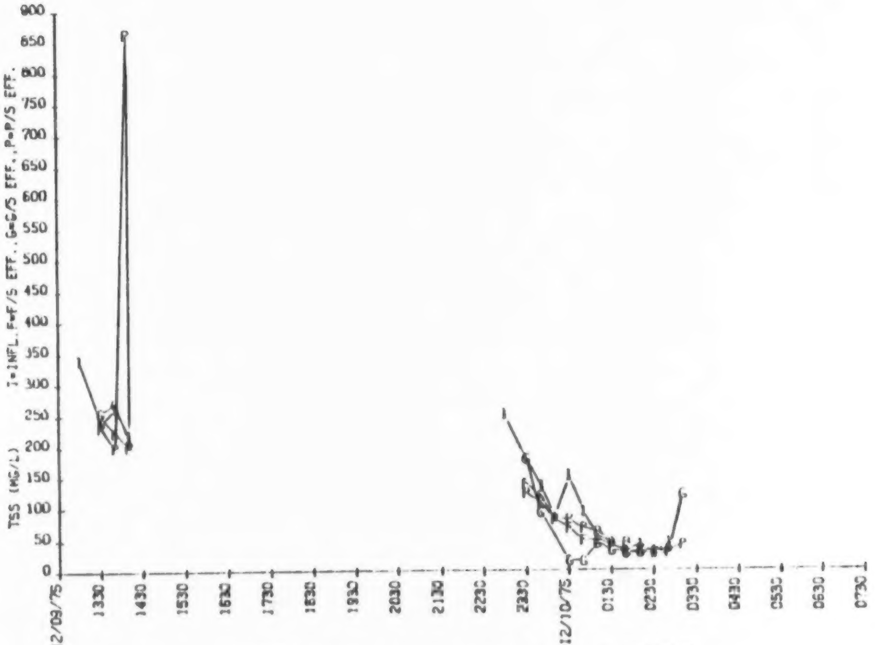
STORM #04 - F/S, G/S, &P/S SYSTEMS



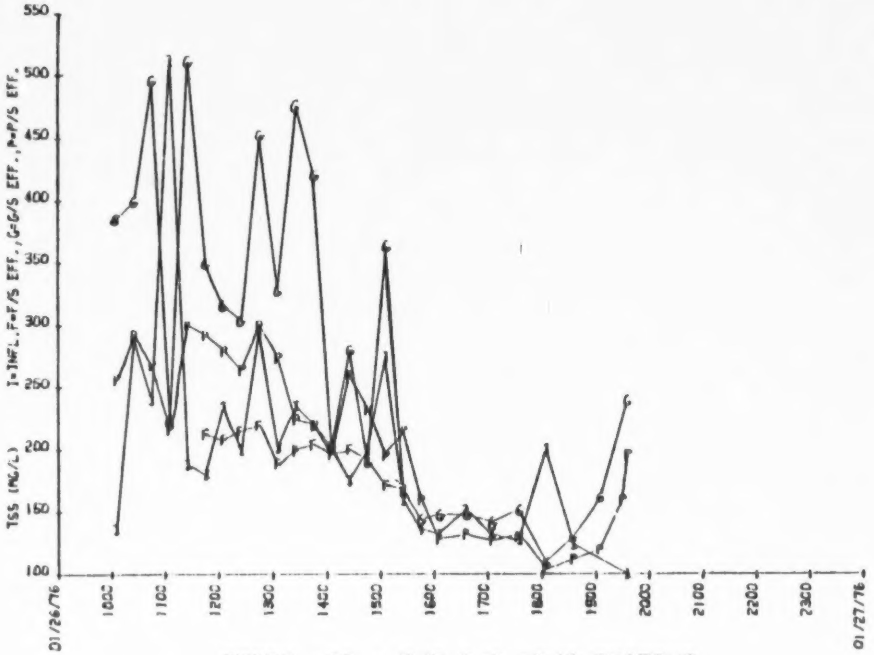
STORM #05 - F/S, G/S, &P/S SYSTEMS



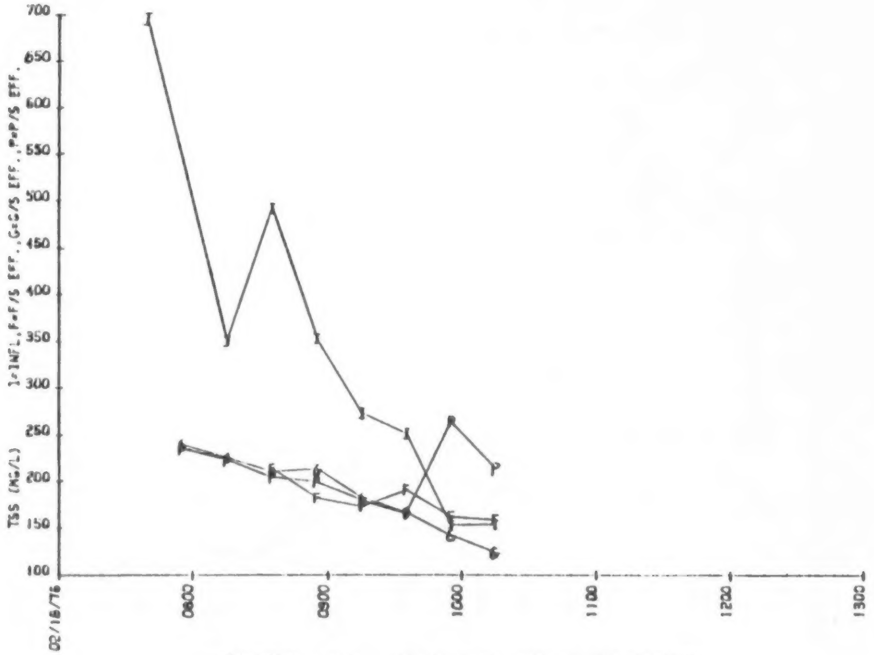
STORM #06 - F/S,G/S,&P/S SYSTEMS



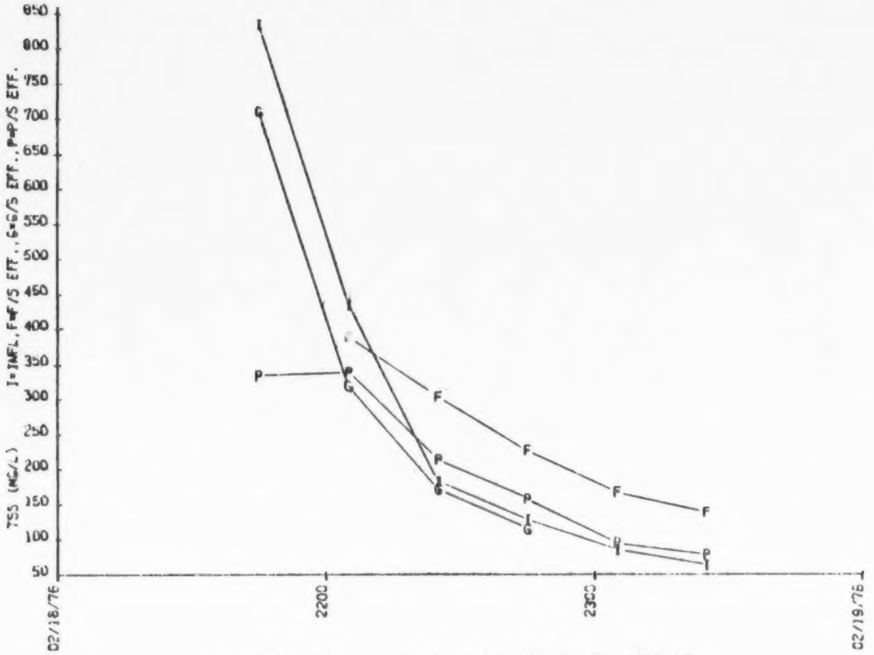
STORM #07 - F/S,G/S,&P/S SYSTEMS



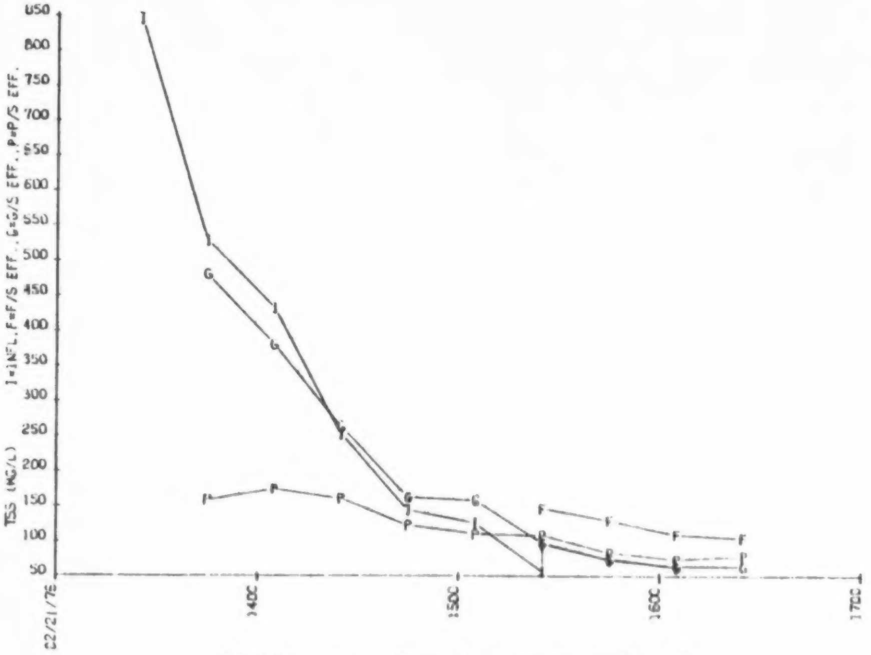
STORM #08 - F/S, G/S, &P/S SYSTEMS



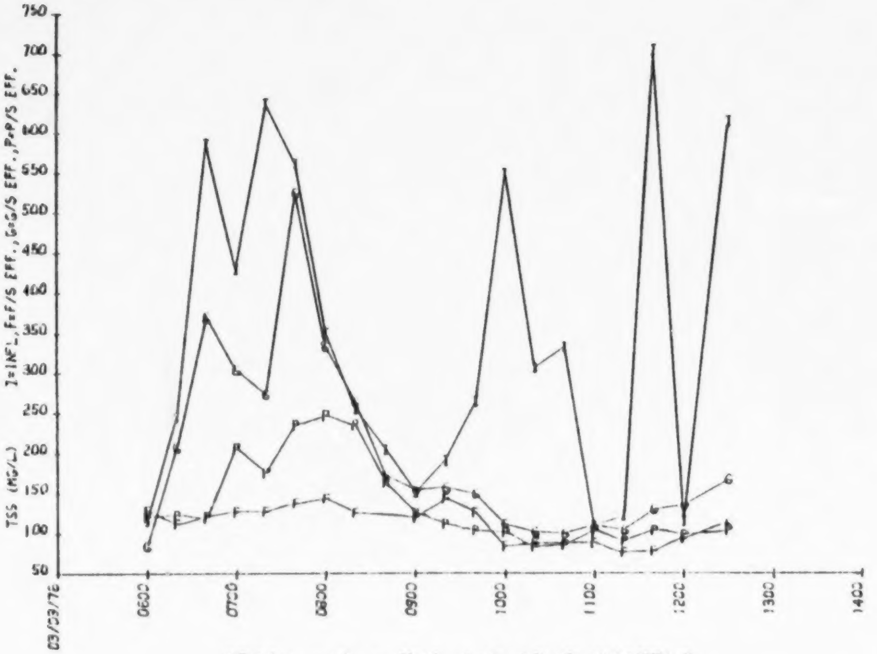
STORM #09 - F/S, G/S, &P/S SYSTEMS



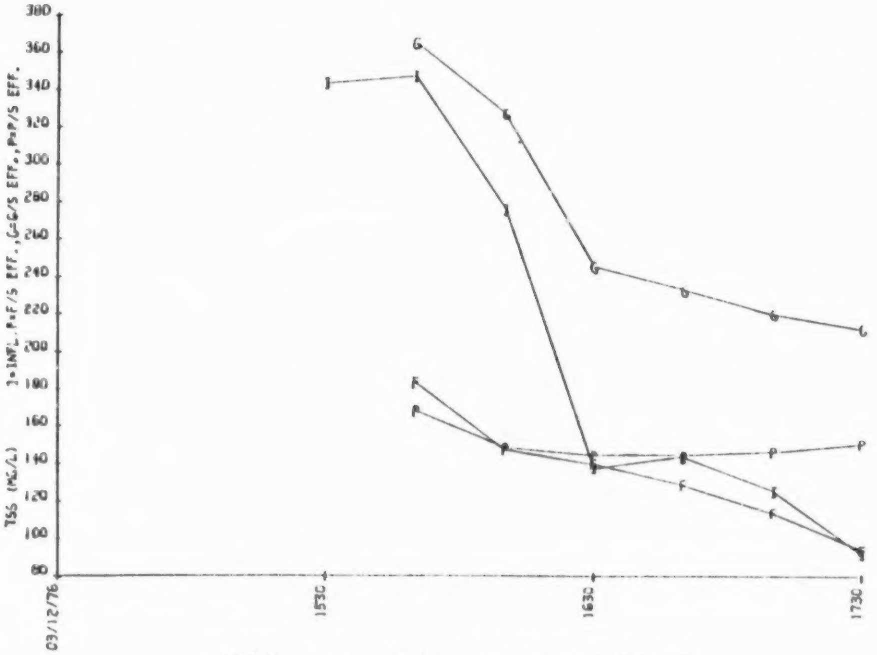
STORM #10 - F/S, G/S, &P/S SYSTEMS



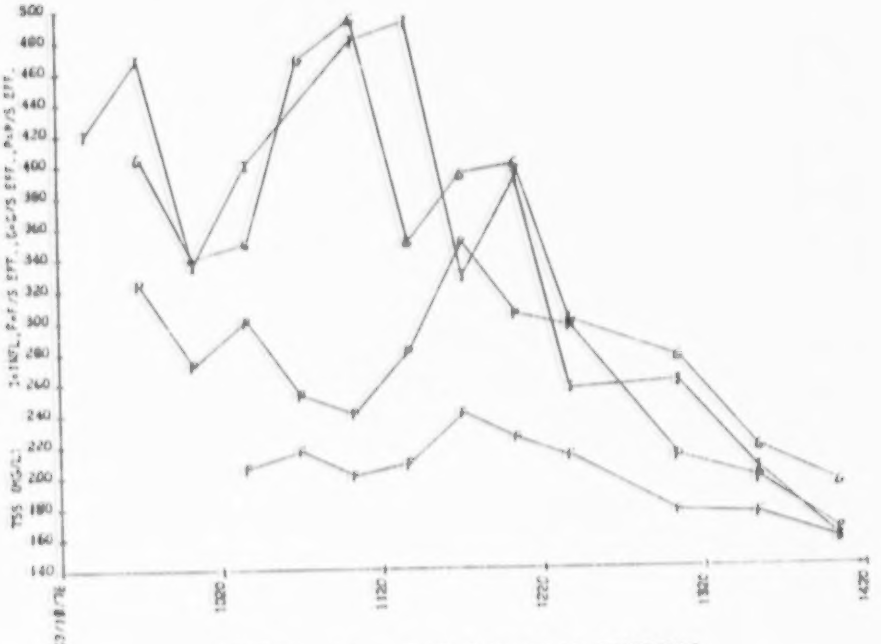
STORM #11 - F/S, G/S, &P/S SYSTEMS



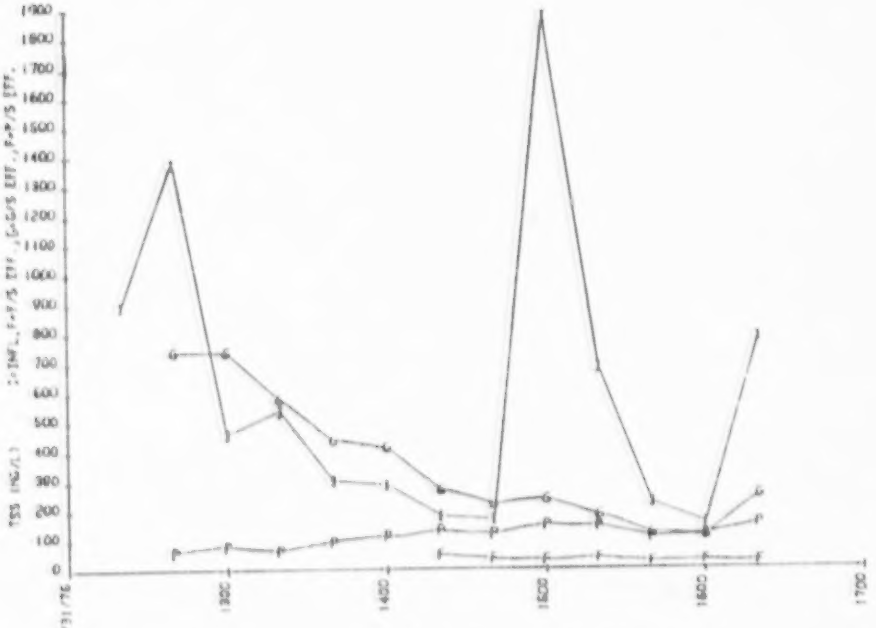
STORM #12 - F/S, G/S, &P/S SYSTEMS



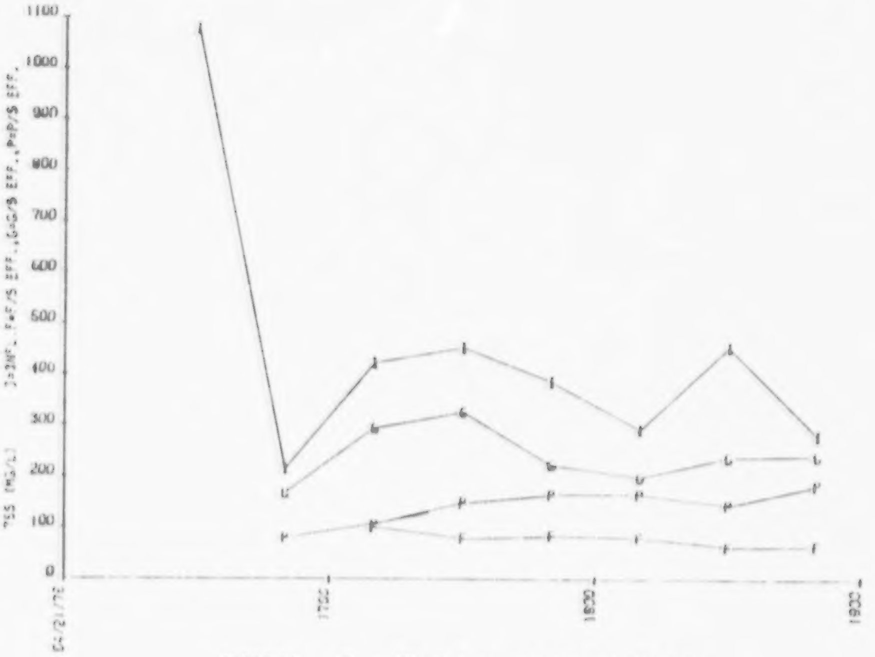
STORM #13 - F/S, G/S, &P/S SYSTEMS



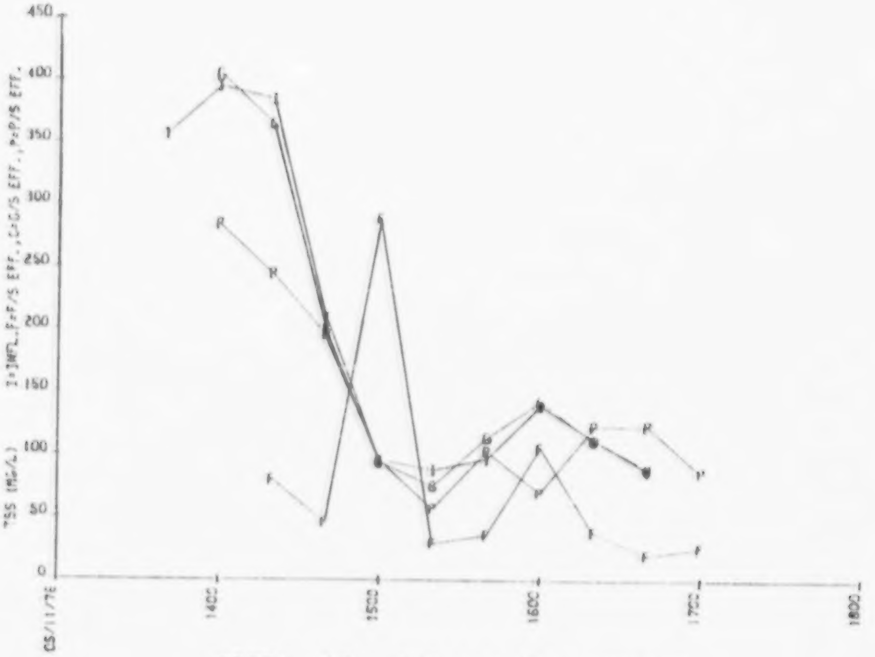
STORM #14 - F/S, G/S, &P/S SYSTEMS



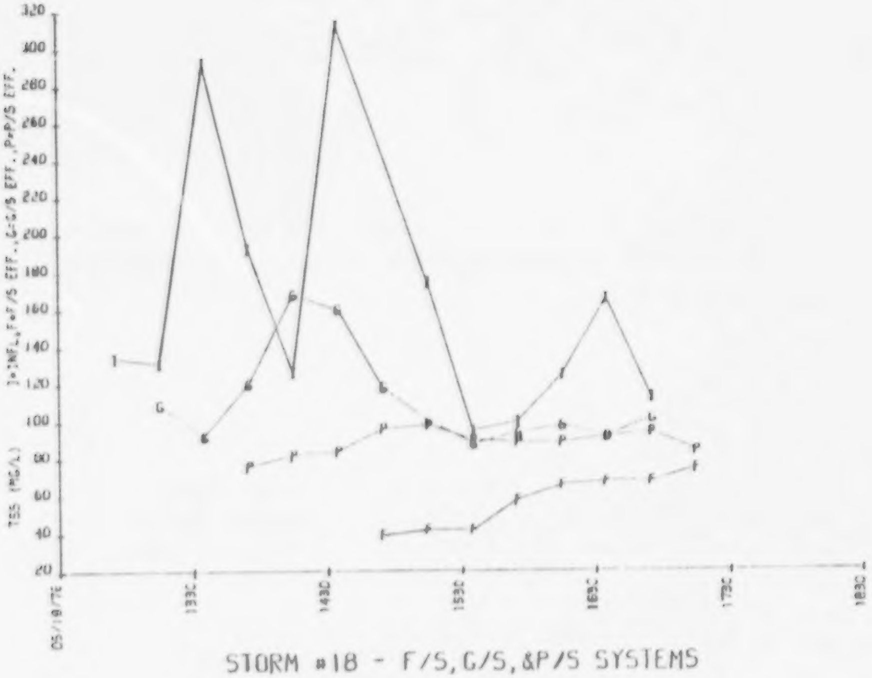
STORM #15 - F/S, G/S, &P/S SYSTEMS



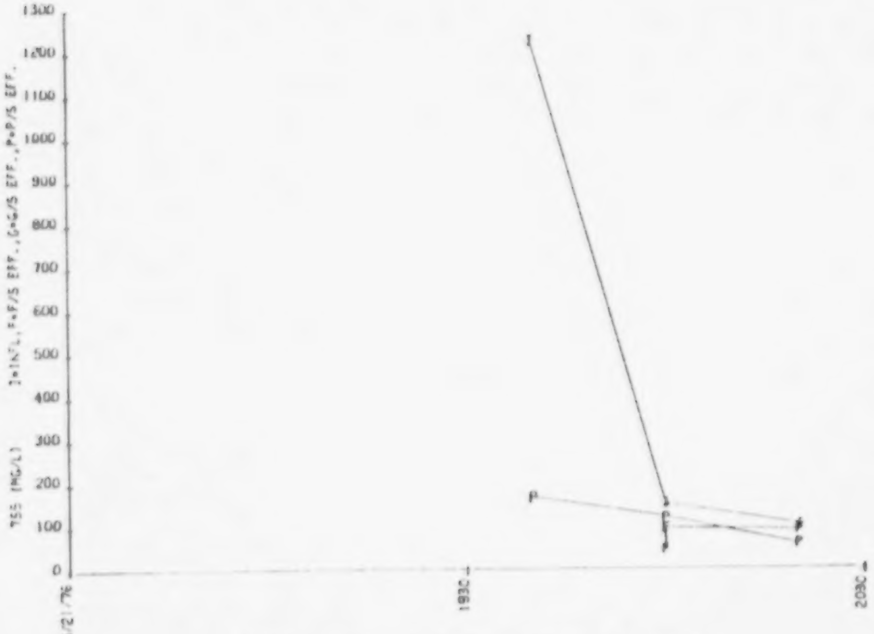
STORM #16 - F/S, G/S, &P/S SYSTEMS



STORM #17 - F/S, G/S, &P/S SYSTEMS



STORM #18 - F/S, G/S, &P/S SYSTEMS



STORM #19 - F/S, G/S, &P/S SYSTEMS

Reproduced from
best available copy.

APPENDIX B
Statistical Analysis of Influent and Effluent Data Flocculation/Sedimentation and Swirl Concentrators

Note: The tables in Appendices B, C and D were developed by a generalized computer routine. The number of significant digits displayed does not reflect the accuracy of the analyses.

Concentrations of all parameters except pH, SETTS and F.Coli are expressed as mg/l. SETTS concentrations are expressed as ml/l. F.Coli concentrations are expressed as colonies/100 ml.

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM          AUG 24, 1976          10106

                    ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 01)

PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION    SKEWNESS      KURTOSIS
----------- ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              6    46.0000       359.000       189.000       132.289       98.0884       1.10919       3.20409
VSS              6    8.70000       67.0000       28.1167       24.9780       11.8209     .700721E-01     2.33277
TS               0
VS               0
SETTS            0
BOD5             6    2.60000       38.0000       11.9500       7.82084       12.2161       1.46237       3.55944
COD             15    .000000       16.0000       7.93333       .000000       4.26562       .334634       2.61159
TOC             15    4.00000       47.0000       22.0667       16.6739       14.8129       .390060       1.69190
O&G              6    4.00000       32.0000       13.3333       9.36805       11.2793       .745019       1.70109
PH              15    5.60000       6.50000       6.10666       6.10389       .193620       .838100       2.60993
TKN             15    .200000       .890995       .346666       .291198       .227645       1.14519       2.61461
TIP             15  .600000E-01     .200000       .110666       .103318     .821967E-01     .704785       2.23575
AL               0
FCOLI            0

                    ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 02)

PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION    SKEWNESS      KURTOSIS
----------- ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              0
VSS              0
TS               0
VS               0
SETTS            0
BOD5             0
COD              8    11.0000       39.0000       30.3750       28.2318       9.66073       .905750       2.47616
TOC              8    23.0000       99.0000       55.0000       48.2182       22.7596       .615067       2.63992
O&G              5    19.2000       36.0000       29.6000       28.9208       5.88557       .827791       2.44630
PH               5    5.60000       5.80000       5.71999       5.71915     .979795E-01     .408015       1.16050
TKN              8    1.20000       6.10000       2.90000       2.63480       1.36290       1.35330       4.12981
TIP              8    .100000       .690000       .277500       .237370       .165057       1.21356       3.49812
AL               0
FCOLI            0

                    ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 03)

PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION    SKEWNESS      KURTOSIS
----------- ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS             17    35.0000       470.000       187.176       137.722       136.919       .812030       2.55301
VSS             17    10.0000       270.000       91.0706       58.9750       77.7499       .908705       2.99768
TS              17    90.0000       610.000       235.647       185.661       157.450       .887958       2.88692
VS              17    6.00000       376.000       102.000       56.8140       103.280       1.35582       3.82696
SETTS           17    .300000       25.0000       6.82941       2.64045       9.04074       2.35886       8.45175
BOD5            16    5.00000       280.000       56.1875       29.6316       68.6125       2.23237       7.52120
COD              1    97.0000       97.0000       97.0000       96.9997       .000000       .000000       .000000
TOC             17    5.00000       61.0000       25.5294       20.4507       15.4962       .601954       2.54550
O&G              9    8.00000       41.0000       27.0000       24.1915       10.9969       .264326       1.72432
PH               9    5.60000       6.30000       5.87999       5.87700       .188562       .897272       3.12696
TKN             17    .300000       4.40000       1.41765       1.10330       1.02912       1.39811       4.60467
TIP             17    .009000       .730000       .260117       .000000       .231943       .607915       1.91025
AL               0
FCOLI            0

                    ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 04)

PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION    SKEWNESS      KURTOSIS
----------- ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS             12    52.0000       475.000       196.750       160.648       124.605       1.23235       3.32581
VSS             12    32.0000       224.000       106.250       92.0946       57.6962       1.01155       3.08488
TS               0
VS               0
SETTS            0
BOD5             0
COD              0
TOC              0
O&G              0
PH               0
TKN              0
TIP              0
AL               0
FCOLI            0

                    ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 05)

PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION    SKEWNESS      KURTOSIS
----------- ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              7    24.0000       140.000       84.5714       71.1363       46.4614     .707700E-01     1.43589
VSS              7    12.0000       80.0000       41.1429       31.4398       26.0510       .337900       1.87031
TS               9    296.000       969.000       647.555       610.070       203.450       1.70187       4.91415
VS               9    103.000       585.000       198.000       164.205       148.901       1.88093       5.16028
SETTS            0
BOD5             9    30.0000       3300.00       815.555       340.967       1006.71       1.58021       4.30994
COD              0
TOC              9    56.0000       530.000       183.889       109.667       140.519       2.22767       6.37750
O&G              5    3.60000       101.600       34.2400       20.3630       38.7430       1.27683       2.96791
PH               9    5.80000       6.80000       6.22222       6.21330       .332592       .250350       1.83651
TKN              9    3.70000       17.6000       6.94444       6.19702       3.99661       1.97960       5.70077
TIP              9    .610000       4.50000       1.99111       1.40931       1.47287       .620061       1.70696
AL               9    .000000       5.00000       1.66667       .000000       1.49071       .903871       3.21000
FCOLI            0
```

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM          AUG 24, 1976          10106

                         ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 06)

 PARAMETER    POINTS    MINIMUM        MAXIMUM        AVERAGE       GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------- ------ -------------- -------------- -------------- -------------- -------------- -------------- --------------
TSS               12    36.0000        244.000        107.333        87.7505        71.6769        .920561        2.21133
VSS               12    12.0000        120.000        60.6667        49.6393        36.5087        .697723        2.11760
TS                13    235.000        480.000        333.615        324.200        81.6545        .662221        2.08086
VS                13    88.0000        239.000        152.231        147.734        36.7657        .406623        3.67424
SETTS              4    1.00000        5.00000        2.25000        1.83142        1.60078        1.09702        2.29447
BOD5              13    8.00000        60.0000        25.0000        20.5782        16.1436        .951652        2.96378
COD               13    22.0000        32.0000        25.6154        25.4100        3.30062        .831024        2.66950
TOC               13    23.0000        79.0000        32.3077        30.5459        13.8530        2.08069        9.96398
O&G                6    .000000        6.40000        1.26667        .000000        2.33714        1.65988        3.93642
PH                13    6.10000        7.00000        6.79999        6.79569        .241788        1.79576        5.59957
TKN               13    1.70000        4.10000        2.57692        2.49574        .684053        .945496        2.80907
TIP               13    .330000        .730000        .557692        .545705        .110951        .295618        2.37333
AL                13    1.00000        4.50000        2.42308        2.27726        .851382        .801542        3.60286
FCOLI              0

                         ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 7A)

 PARAMETER    POINTS    MINIMUM        MAXIMUM        AVERAGE       GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------- ------ -------------- -------------- -------------- -------------- -------------- -------------- --------------
TSS                4    220.000        340.000        266.000        262.378        45.4753        .771733        2.04139
VSS                4    124.000        200.000        161.000        156.189        30.7734        .505861        1.70577
TS                 4    1133.00        2014.00        1559.75        1523.38        338.923        .900938E-01    1.54183
VS                 4    135.000        150.000        143.000        142.862        6.20484        .678147        2.09485
SETTS              4    4.60000        6.00000        5.40000        5.36423        .616441        .153673        1.20221
BOD5               4    72.0000        95.0000        83.0000        82.4734        9.35414        .824692E-01    1.27589
COD                4    45.0000        78.0000        55.5000        54.6414        13.5000        .921811        2.11203
TOC                4    50.0000        73.0000        62.5000        61.6589        10.1612        .857842E-01    1.12279
O&G                0
PH                 4    6.80000        7.30000        7.07499        7.07131        .227761        .713316E-01    1.09464
TKN                4    4.00000        5.70000        4.62500        4.57013        .701338        .550333        1.69627
TIP                4    .590000        .660000        .632500        .631605        .294746E-01    .362442        1.46767
AL                 4    .000000        1.20000        .600000        .000000        .600000        .000000        1.00000
FCOLI              0
                         ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 7B)

 PARAMETER    POINTS    MINIMUM        MAXIMUM        AVERAGE       GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------- ------ -------------- -------------- -------------- -------------- -------------- -------------- --------------
TSS               12    28.0000        252.000        95.4166        74.4156        67.9351        .962357        2.85586
VSS               12    13.3000        172.000        62.1500        46.8397        46.9302        1.00401        3.03538
TS                12    760.000        1642.00        993.500        970.649        236.367        1.74695        5.11824
VS                12    4.00000        127.000        49.3333        35.7059        35.1267        .803563        2.67312
SETTS             12    .100000        5.40000        1.25000        .409984        1.66500        1.16090        3.65469
BOD5              12    8.00000        66.0000        27.3667        21.7449        17.9026        .723395        2.45644
COD               12    22.0000        47.0000        26.1667        25.4252        7.17440        2.05705        6.09702
TOC               12    3.00000        49.0000        18.0833        14.1454        12.4195        1.08008        3.50435
O&G                0
PH                12    6.60000        7.40000        7.02500        7.02031        .255359        .309610        1.70900
TKN               12    .800000        11.5000        1.90000        1.21780        2.90003        2.96614        9.90830
TIP               12    .130000        .250000        .184166        .181831        .295607E-01    .460981        3.25630
AL                12    .000000        1.20000        .500000        .000000        .288675        .914527        3.83520
FCOLI              0

                         ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 08)

 PARAMETER    POINTS    MINIMUM        MAXIMUM        AVERAGE       GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------- ------ -------------- -------------- -------------- -------------- -------------- -------------- --------------
TSS               25    106.000        512.000        201.880        189.121        81.9197        2.06970        8.61099
VSS               25    52.0000        228.000        111.160        105.468        36.8713        1.19319        5.01898
TS                25    1230.00        3017.00        1984.16        1908.38        551.469        .327156        1.73193
VS                25    98.0000        273.000        169.840        162.560        49.8892        .400930        2.40192
SETTS             25    .100000        9.00000        2.90400        2.13409        2.13269        1.21579        3.91044
BOD5              25    38.0000        201.000        76.4400        71.4582        32.3708        2.14409        9.09765
COD               25    33.0000        205.000        101.200        86.0906        55.3114        .477886        1.70903
TOC               25    20.0000        94.0000        51.3200        48.3107        17.7919        .624669        2.75619
O&G                0
PH                25    6.15000        6.95000        6.51399        6.51121        .188955        .839988E-01    2.29800
TKN               25    1.90000        6.10000        3.10000        3.04836        .970472        1.20696        4.59228
TIP               25    .170000        1.24000        .452800        .416867        .201401        2.14665        9.76421
AL                25    .000000        2.80000        1.08000        .000000        .571537        .993077        4.50997
FCOLI              0
                         ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 09)

 PARAMETER    POINTS    MINIMUM        MAXIMUM        AVERAGE       GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------- ------ -------------- -------------- -------------- -------------- -------------- -------------- --------------
TSS                8    154.000        696.000        361.125        302.583        170.064        .860842        2.82465
VSS                8    75.0000        392.000        186.875        158.588        109.416        .814082        2.23060
TS                 8    413.000        602.000        526.750        523.117        59.7867        .730852        2.35141
VS                 8    30.0000        150.000        86.7500        74.4700        44.0561        .769877E-01    1.31586
SETTS              8    .900000        3.40000        1.88750        1.71081        .856501        .702485        2.06076
BOD5               8    21.0000        38.0000        30.8750        30.1819        6.31343        .349398        1.90627
COD                7    6.00000        17.0000        11.5714        11.0447        3.33197        .658388E-01    2.22825
TOC                7    23.0000        46.0000        32.2857        31.3869        7.81416        .512421        1.83970
O&G                0
PH                 8    6.80000        7.30000        7.17499        7.17325        .196125        1.55190        4.32127
TKN                7    .180000        2.28000        1.00428        .765762        .673325        .337986        2.32381
TIP                7    .140000        .350000        .241428        .216779        .132280        1.69075        4.31139
AL                 8    3.66000        26.9200        7.38000        5.67237        7.40935        2.23021        6.06999
FCOLI              0
```

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM          AUG 24, 1976          10106
                                ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 10)

 PARAMETER   POINTS    MINIMUM        MAXIMUM        AVERAGE        GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------ ------ -------------- -------------- -------------- -------------- -------------- -------------- --------------
TSS               6    64.0000        834.000        288.833        190.479        272.780        1.15178        2.82384
VSS               6    26.0000        320.000        120.667        83.6491        103.741        .993208        2.49727
TS                6    486.000        1120.00        624.000        593.650        225.838        1.65745        3.93028
VS                6    74.0000        353.000        142.667        120.744        97.3288        1.55124        3.71516
SETTS             6    .100000        7.50000        2.48333        1.23799        2.55435        1.07222        2.68071
BODS              6    31.0000        130.000        58.6667        51.3185        34.0016        1.34429        3.33777
COD               4    11.0000        27.0000        16.7500        15.6890        6.33936        .765089        1.95066
TOC               4    20.0000        123.000        57.2500        44.0098        41.1240        .715503        1.89044
O&G               0
PH                6    6.90000        7.40000        7.16666        7.16463        .169967        .286543        1.81949
TKN               4    .640000        .960000        .822500        .810049        .141134        .148559        1.19557
TIP               4    .150000        .370000        .277500        .263453        .880285E-01    .599184        2.02490
AL                4    3.60000        7.69000        5.00000        4.75726        1.65304        .791010        2.00008
FCOLI             0
                                ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 11)

 PARAMETER   POINTS    MINIMUM        MAXIMUM        AVERAGE        GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------ ------ -------------- -------------- -------------- -------------- -------------- -------------- --------------
TSS              10    57.0000        865.000        261.500        171.353        263.468        1.24324        3.35005
VSS              10    32.0000        445.000        126.600        85.8427        124.332        1.59118        4.47503
TS               10    442.000        9502.00        1878.70        751.006        2679.76        2.64729        8.04084
VS               10    76.0000        9044.00        1325.60        181.401        2674.01        2.66221        8.09702
SETTS            10    .300000        10.5000        2.91000        1.55340        3.20170        1.27782        3.63033
BODS             10    18.0000        125.000        45.7000        37.2685        32.3668        1.30735        3.84906
COD               0
TOC              10    12.0000        96.0000        32.7000        26.2655        24.6963        1.60255        4.51915
O&G               0
PH               10    7.60000        8.50000        8.08999        8.08570        .262488        .222060        2.22599
TKN              10    1.40000        6.50000        2.68000        2.45204        1.35410        2.10434        6.44032
TIP              10    .220000        .430000        .294000        .286082        .713021E-01    .690024        2.03050
AL                9    .000000        1.70000        .611111        .000000        .779521        .838661        1.47955
FCOLI             0
                                ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 12)

 PARAMETER   POINTS    MINIMUM        MAXIMUM        AVERAGE        GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------ ------ -------------- -------------- -------------- -------------- -------------- -------------- --------------
TSS              24    102.000        706.000        321.375        266.009        191.395        .563623        1.96301
VSS              23    42.0000        541.000        191.739        146.040        140.483        1.03328        3.09784
TS               22    829.000        2963.00        1433.41        1354.67        515.317        1.27040        4.44017
VS               22    147.000        464.000        226.045        215.634        77.4651        1.67066        5.36819
SETTS            24    1.00000        6.10000        2.77083        2.51733        1.28347        .946742        3.37225
BODS             23    22.0000        264.000        95.6522        77.8176        62.9875        1.15338        3.49723
COD               0
TOC              24    13.0000        76.0000        33.3333        30.5913        13.9662        .948330        4.40591
O&G               0
PH               24    6.40000        7.00000        6.67916        6.67600        .204082        .406559E-01    1.80630
TKN              24    2.00000        6.10000        3.52083        3.38659        1.03802        1.17227        3.86635
TIP              24    .700000E-01    18.9000        3.42416        1.15871        5.62119        1.91610        5.14114
AL               24    .000000        2.40000        .749996        .000000        .533673        .757529        4.76617
FCOLI             0

                                ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 13)

 PARAMETER   POINTS    MINIMUM        MAXIMUM        AVERAGE        GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------ ------ -------------- -------------- -------------- -------------- -------------- -------------- --------------
TSS              15    92.0000        383.000        218.333        195.485        91.0520        .456369        1.88874
VSS              15    62.0000        309.000        147.600        132.116        69.5470        .658958        2.87318
TS               15    607.000        1098.00        749.667        738.393        136.521        1.06633        3.30338
VS               15    111.000        373.000        195.733        181.201        82.7480        1.08058        2.82334
SETTS            15    .300000        18.5000        5.74666        4.00154        4.56243        1.31219        4.63731
BODS             15    55.0000        168.000        109.733        102.249        40.3062        .208962        1.41036
COD               0
TOC              15    37.0000        109.000        62.8667        60.4591        18.0402        .796376        3.22601
O&G               8    39.2000        93.6000        66.8000        64.1708        17.8519        .229162        2.02469
PH               15    6.50000        7.40000        7.00666        7.00160        .264491        .492727        2.23129
TKN              15    4.31000        6.84000        5.46466        5.42210        .692751        .501140        2.40104
TIP              15    .420000        1.11000        .642666        .619436        .183065        1.13599        3.59723
AL               15    .000000        .800000        .533333E-01    .000000        .199555        3.47409        13.0714
FCOLI             0
                                ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 14)

 PARAMETER   POINTS    MINIMUM        MAXIMUM        AVERAGE        GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------ ------ -------------- -------------- -------------- -------------- -------------- -------------- --------------
TSS              12    158.000        492.000        349.417        330.725        106.551        .297219        1.86131
VSS              12    62.0000        248.000        146.167        133.588        57.5682        .840735E-02    1.72500
TS               12    898.000        1796.00        1361.33        1326.58        298.656        .197665        1.65238
VS               12    108.000        306.000        222.333        213.014        60.0449        .336680        2.18860
SETTS             4    6.00000        7.50000        6.75000        6.72675        .559017        .000000        1.64000
BODS             12    75.0000        210.000        141.833        135.122        41.6870        .833302E-01    2.04484
COD               0
TOC               6    63.0000        270.000        129.167        114.471        68.6037        1.18969        3.18380
O&G               6    31.0000        60.0000        48.1333        46.6670        11.3155        .838568        1.49630
PH                6    7.30000        7.90000        7.63333        7.63119        .179506        .505739        2.80016
TKN               6    3.40000        5.50000        4.16666        4.12188        .644936        1.17687        3.39015
TIP               6    .450000        1.21000        .869999        .819713        .281365        .185195        1.43481
AL                6    1.20000        5.60000        3.40000        3.05783        1.60000        .810908E-05    2.11953
FCOLI             1    20.0000        20.0000        20.0000        20.0000        .000000        .000000        .000000
```

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM          AUG 25, 1976          08149

                              ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 15)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              13   158.000       1875.00       611.692       449.561       500.743       1.29702       3.74211
VSS              13   33.0000       1010.00       283.077       162.185       293.651       1.36444       3.72589
TS               13   354.000       2056.00       887.615       742.809       562.001       1.11083       3.00295
VS               12   116.000       1202.00       426.583       311.579       361.928       1.34619       3.41028
SETTS             5   2.50000       17.0000       9.98000       7.89882       6.41922       .220144       1.23561
BOD5             13   42.0000       510.000       170.923       121.370       138.741       1.01024       3.14930
COD               0
TOC               5   9.00000       270.000       92.8000       55.9361       91.2368       1.27913       3.00148
O&G               7   18.8000       168.000       55.3714       41.5514       48.4813       1.64020       4.26820
PH                5   6.80000       7.40000       7.19999       7.19686       .209762       1.17007       2.83044
TKN               5   1.80000       9.80000       5.24000       4.16883       3.26717       .274818       1.35363
TIP               5   .230000       2.00000       1.19800       .855157       .753748       .352322       1.22133
AL                5   .860000       2.00000       1.32000       1.26393       .391918       .567722       2.43620
FCOLI             0
                              ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 16)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              10   216.000       1812.00       566.100       465.370       475.619       1.80369       4.91556
VSS              10   56.0000       620.000       208.200       155.245       176.158       1.40832       3.56503
TS               10   371.000       955.000       580.200       554.013       181.491       .696807       2.33606
VS               10   116.000       358.000       183.300       170.298       76.2011       1.14796       3.11469
SETTS             4   .800000       4.00000       1.75000       1.39985       1.30671       1.11431       2.30242
BOD5             10   23.0000       114.000       56.2000       48.7082       29.8857       .501622       1.97280
COD               0
TOC              10   28.0000       92.0000       50.9000       47.7090       18.8862       .837597       2.87192
O&G               5   13.2000       58.8000       31.7600       27.4060       16.6788       .327290       1.32482
PH               10   7.00000       7.30000       7.12000       7.11918       .107703       .769826E-01   1.51844
TKN              10   1.10000       5.80000       2.74000       2.24791       1.71883       .602549       1.70153
TIP              10   .140000       2.36000       .496999       .306025       .649892       2.29405       6.81235
AL               10   1.00000       8.00000       3.68000       2.94354       2.41901       .651115       1.86011
FCOLI             0
                              ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 17)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              10   88.0000       395.000       196.700       162.519       124.271       .885099       1.67302
VSS              10   14.0000       260.000       115.800       79.2006       89.8095       .819377       1.64888
TS               10   480.000       960.000       646.700       621.531       188.410       .659118       1.80986
VS               10   112.000       406.000       231.700       204.922       116.237       .583956       1.64539
SETTS             4   3.50000       18.0000       10.2500       8.45192       5.79331       .148505       1.35054
BOD5             10   73.0000       318.000       143.600       126.260       77.9784       1.06067       2.89462
COD               0
TOC              10   22.0000       135.000       79.1000       67.2918       39.5283       .659820E-01   1.40896
O&G               5   25.2000       60.0000       41.3600       38.4760       15.4663       .212182       1.23152
PH               10   6.60000       7.20000       6.85999       6.85778       .174356       .172161       2.52287
TKN              10   2.10000       7.60000       3.81000       3.46719       1.76698       .988867       2.60961
TIP              10   .170000       1.64000       .733000       .564611       .501398       .711437       2.10988
AL               10   .000000       2.50000       1.12000       .000000       .867112       .367988       1.55071
FCOLI             0

                              ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 18)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              12   95.0000       312.000       163.333       151.819       68.0580       1.20878       3.15978
VSS              12   20.0000       228.000       93.4167       74.1219       62.1498       .954755       2.90866
TS               12   256.000       771.000       424.667       394.466       153.407       .781994       2.67699
VS               12   90.0000       342.000       167.917       155.260       70.1135       1.09299       3.60976
SETTS             4   2.50000       10.5000       6.62500       5.87874       2.83670       .130912       1.98843
BOD5             12   34.0000       190.000       82.6667       71.4303       46.6946       .976131       2.84926
COD               0
TOC              12   21.0000       114.000       51.2500       44.9047       26.5773       .869144       3.10860
O&G               6   20.4000       134.000       60.3333       50.8669       36.7575       1.08363       2.95548
PH               12   6.80000       7.10000       6.96666       6.96570       .110554       .428705       1.83462
TKN              12   1.30000       8.40000       3.35833       2.69540       2.31281       .921020       2.67929
TIP              12   .260000       1.13000       .555000       .495471       .273450       .834722       2.48318
AL               12   .000000       6.20000       1.76666       .000000       1.39363       .267832       1.72898
FCOLI             0
                              ROCHESTER CSO PP --- PERFORMANCE DATA --- INFLUENT CSO (STORM # 19)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               6   74.0000       1228.00       324.667       183.592       411.060       1.66112       3.94734
VSS               6   28.0000       89.0000       48.8333       41.0494       21.0904       1.35082       3.33776
TS                6   275.000       417.000       366.833       360.948       43.4860       .219629E-01   1.07290
VS                6   52.0000       74.0000       60.6667       59.9305       9.62057       .429297       1.39434
SETTS             2   2.00000       2.50000       2.25000       2.23606       .250000       .000000       1.00000
BOD5              6   25.0000       54.0000       36.8333       35.5806       9.95685       .633575       1.96526
COD               0
TOC               6   8.00000       29.0000       20.6667       19.1623       6.82316       .876013       2.42653
O&G               2   53.2000       55.6000       54.4000       54.3867       1.20000       .000000       1.00000
PH                6   7.30000       8.00000       7.61666       7.61199       .267187       .240834       1.39149
TKN               6   .900000       2.30000       1.40000       1.33301       .461880       .943838       2.69678
TIP               6   .140000       .340000       .206666       .197465       .664997E-01   1.07430       2.95361
AL                6   4.10000       14.0000       7.60000       6.95857       3.28684       .862810       2.78805
FCOLI             0
```

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM          AUG 24, 1976          11112

                        ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 01)

PARAMETER    POINTS   MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN     STD DEVIATION  SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- ------------
TSS               6  168.000       366.000       243.667       236.165       63.1207       .030126       2.77738
VSS               6  .000000       86.0000       32.0000       .000000       33.2415       .517452       1.65006
TS                0
VS                0
SETTS             0
BOD5              0
COD              15  4.00000       24.0000       11.6000       10.2278       5.80556       .808495       2.52321
TOC              15  9.00000       51.0000       22.8000       20.0663       11.7314       .925075       3.10845
O&G               6  .000000       44.0000       21.0000       .000000       15.9696       .557730E-01   1.55464
PH               15  5.75000       6.35000       6.03999       6.03737       .177280       .203357       1.82522
TKN              15  .300000       1.80000       .766666       .627727       .517257       1.11029       2.76055
TIP              15  .600000E-01   .240000       .132000       .119582       .600222E-01   .877626       2.61097
AL                0
FCOLI             0

                        ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 02)

PARAMETER    POINTS   MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN     STD DEVIATION  SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- ------------
TSS               0
VSS               0
TS                0
VS                0
SETTS             0
BOD5              0
COD               9  12.0000       58.0000       37.0000       32.7378       15.9164       .316951       1.48219
TOC               9  30.0000       60.0000       44.3333       42.9323       10.7600       .228625       1.60561
O&G               5  2.00000       24.0000       13.2000       9.89876       7.88416       .348759E-01   1.64068
PH                5  5.70000       6.20000       5.90000       5.89731       .178885       .628943       1.95316
TKN               9  1.40000       7.10000       3.76666       3.17928       2.09973       .386711       1.54352
TIP               9  .180000       .710000       .386666       .331016       .215716       .510504       1.46341
AL                0
FCOLI             8  2000.00       2000.00       2000.00       1999.99       .000000       .000000       .000000
                        ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 03)

PARAMETER    POINTS   MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN     STD DEVIATION  SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- ------------
TSS              17  30.0000       364.000       147.294       122.487       85.0381       .800154       3.25031
VSS              17  12.0000       179.000       62.6470       48.4260       45.2482       1.14918       3.54418
TS               17  75.0000       533.000       221.294       195.091       116.358       1.30115       4.27736
VS               17  29.0000       199.000       82.9412       70.6142       49.5645       1.06808       2.99531
SETTS            17  .100000       3.50000       1.47059       .941665       1.13902       .491913       1.86684
BOD5             17  6.10000       160.000       50.1059       35.6803       41.3163       1.34174       4.01772
COD               0
TOC              17  5.00000       64.0000       24.0235       19.9866       16.2054       .970088       3.03594
O&G     [illegible]  8.00000       41.0000       28.0000       24.0375       10.1735       1.38194       4.23700
PH                8  5.70000       6.30000       6.02500       6.02107       .216506       .249364       1.41171
TKN              17  .700000       6.30000       1.70000       1.43755       1.27510       2.70722       10.0810
TIP              16  .300000E-01   .940000       .358125       .243630       .271137       .605344       2.24037
AL                0
FCOLI            17  200000.       .730000E 07   .161765E 07   988598.       .170172E 07   2.08658       7.50434

                        ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 04)

PARAMETER    POINTS   MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN     STD DEVIATION  SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- ------------
TSS               5  100.000       296.000       212.400       194.126       81.8623       .288413       1.31447
VSS               5  20.0000       135.000       89.6000       75.1095       40.3516       .618376       2.19647
TS                0
VS                0
SETTS             0
BOD5              0
COD               0
TOC               0
O&G               0
PH                0
TKN               0
TIP               0
AL                0
FCOLI             3  .102000E 07   .900000E 07   .377333E 07   .228517E 07   .369758E 07   .704067       1.50000
                        ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 05)

PARAMETER    POINTS   MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN     STD DEVIATION  SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- ------------
TSS               5  63.0000       164.000       101.400       93.9815       40.0779       .496351       1.58573
VSS               4  52.0000       132.000       89.0000       82.4110       33.8674       .107038       1.19330
TS                0
VS                0
SETTS             0
BOD5              8  300.000       1530.00       630.000       500.075       480.469       1.13816       2.38178
COD               4  33.0000       47.0000       38.0000       37.6533       5.33854       .966162       2.22161
TOC               8  59.0000       161.000       100.500       94.5358       36.6742       .770414       2.02179
O&G               4  .000000       37.6000       15.6000       6.05570       14.7486       .451108       1.60362
PH                8  6.20000       7.00000       6.63750       6.63370       .223257       .340084       2.80055
TKN               8  3.40000       10.6000       6.25000       5.97637       1.96023       1.02083       3.43012
TIP               8  .650000       3.52000       1.50750       1.29371       .898411       1.22660       3.41789
AL                7  1.00000       3.00000       2.28571       2.15522       .699854       .459279       2.10417
FCOLI             0
```

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM          AUG 24, 1976          31112

                        ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 06)

 PARAMETER   POINTS    MINIMUM        MAXIMUM        AVERAGE        GEO. MEAN     STD DEVIATION    SKEWNESS       KURTOSIS
------------ ------ -------------- -------------- -------------- -------------- -------------- -------------- --------------
TSS              13   62.0000        200.000        128.538        123.364        35.5649        .246000        2.84450
VSS              13   24.0000        92.0000        51.0769        47.3397        20.4053        .777238        2.52626
TS                0
VS                0
SETTS             4   1.00000        3.00000        1.75000        1.61185        .750000        .848889        2.18518
BOD5             13   5.00000        33.0000        16.0000        13.8558        8.33697        .666982        2.48376
COD              13   24.0000        37.0000        28.1538        27.9503        3.50486        1.05101        3.59252
TOC              13   16.0000        57.0000        30.6154        29.1181        10.1036        1.07106        4.10555
O&G               6   .000000        8.00000        1.33333        .000000        2.98142        1.78885        4.20000
PH               13   5.90000        6.70000        6.20000        6.19460        .260177        .576583        2.08165
TKN              13   1.80000        3.20000        2.36154        2.29490        .558209        .143808        1.63201
TIP              13   .330000        .760000        .561538        .547174        .124644        .369417E-01    2.04023
AL               13   .000000        3.00000        2.11538        .000000        .788227        1.20802        4.42678
FCOLI            12   270000.        .122000E 07    571850.        511547.        291877.        1.15713        2.95109
                        ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 7A)

 PARAMETER   POINTS    MINIMUM        MAXIMUM        AVERAGE        GEO. MEAN     STD DEVIATION    SKEWNESS       KURTOSIS
------------ ------ -------------- -------------- -------------- -------------- -------------- -------------- --------------
TSS               3   200.000        248.000        224.000        223.139        19.5959        .000000        1.50000
VSS               3   80.0000        100.000        88.0000        87.5901        8.64098        .595170        1.50000
TS                0
VS                0
SETTS             3   2.50000        3.30000        2.83333        2.81366        .339934        .528004        1.50000
BOD5              3   76.0000        82.0000        78.6667        78.6271        2.49444        .381814        1.50001
COD               3   46.0000        73.0000        56.6667        55.5327        11.7284        .611949        1.50000
TOC               3   52.0000        82.0000        62.3333        60.9111        13.9124        .704368        1.50000
O&G               0
PH                3   7.00000        7.40000        7.26666        7.26418        .188562        .707046        1.49994
TKN               3   5.00000        5.50000        5.16667        5.16140        .235702        .707115        1.50001
TIP               3   .590000        .920000        .723333        .710223        .141970        .580388        1.50001
AL                3   1.20000        1.60000        1.46667        1.45378        .188562        .707106        1.50000
FCOLI             1   .100000E 07    .100000E 07    .100000E 07    999987.        .000000        .000060        .000000
                        ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 7B)

 PARAMETER   POINTS    MINIMUM        MAXIMUM        AVERAGE        GEO. MEAN     STD DEVIATION    SKEWNESS       KURTOSIS
------------ ------ -------------- -------------- -------------- -------------- -------------- -------------- --------------
TSS              11   25.0000        140.000        59.9091        50.3316        37.4225        1.03543        2.73446
VSS              11   4.00000        62.0000        21.7273        15.8934        17.2789        1.09426        3.12566
TS                1   932.000        932.000        932.000        931.997        .000000        .000000        .000000
VS                1   46.0000        46.0000        46.0000        45.9999        .000000        .000000        .000000
SETTS            11   .100000        1.70000        .500000        .240119        .569298        1.06880        2.49920
BOD5             11   10.9000        55.0000        23.1818        19.9637        13.7439        1.15747        3.39722
COD              11   20.0000        42.0000        25.3636        24.7749        6.10919        1.82034        5.21004
TOC              11   8.00000        32.0000        15.4545        14.2537        6.74689        1.27670        3.75720
O&G               0
PH               11   6.80000        7.40000        7.13636        7.13336        .205704        .368661        1.90008
TKN              11   .800000        2.10000        1.43636        1.35769        .453617        .361140        1.58198
TIP              11   .160000        .400000        .238182        .228205        .724654E-01    .853149        2.84287
AL               12   .400000        1.20000        .500000        .484415        .238047        2.22398        6.46713
FCOLI             6   595000.        .142000E 07    928333.        869461.        340694.        .494090        1.46847
                        ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 08)

 PARAMETER   POINTS    MINIMUM        MAXIMUM        AVERAGE        GEO. MEAN     STD DEVIATION    SKEWNESS       KURTOSIS
------------ ------ -------------- -------------- -------------- -------------- -------------- -------------- --------------
TSS              12   168.000        220.000        197.917        197.297        15.3539        .388367        2.45491
VSS              12   52.0000        71.0000        57.7500        57.5089        5.41795        1.02982        3.47488
TS                0
VS                0
SETTS            12   .600000        1.60000        1.10833        1.03826        .379601        .643420E-01    1.43031
BOD5             12   74.0000        105.000        89.0000        88.5752        8.61800        .119770        2.51953
COD               9   127.000        187.000        157.222        155.786        21.1806        .545654E-01    1.61973
TOC              13   35.0000        63.0000        49.2308        48.3620        9.10750        .940811E-01    1.55152
O&G               0
PH               13   6.25000        6.70000        6.44615        6.44473        .135109        .268766        2.20381
TKN              12   3.10000        4.40000        3.87499        3.85468        .389711        .411260        2.12522
TIP              12   .600000        1.18000        .855833        .837109        .182001        .426001        1.88779
AL               12   .800000        2.00000        1.30000        1.27004        .288675        .914530        3.83921
FCOLI            12   780000.        .160500E 07    .115417E 07    .113412E 07    213706.        .226205        2.08600
                        ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 09)

 PARAMETER   POINTS    MINIMUM        MAXIMUM        AVERAGE        GEO. MEAN     STD DEVIATION    SKEWNESS       KURTOSIS
------------ ------ -------------- -------------- -------------- -------------- -------------- -------------- --------------
TSS               6   160.000        214.000        181.000        180.095        18.3848        .385769        2.19185
VSS               6   71.0000        92.0000        80.8333        80.5334        6.96220        .100971        1.94383
TS                0
VS                0
SETTS             6   .100000        .300000        .166667        .151309        .745355E-01    .626100        2.00000
BOD5              6   15.0000        45.0000        26.0000        23.3791        12.5033        .673253        1.54043
COD               6   10.0000        16.0000        13.1667        12.9901        2.11476        .219299        1.65677
TOC               6   22.0000        50.0000        29.6667        28.5481        9.26762        1.63394        3.95246
O&G               0
PH                6   6.80000        8.00000        7.41666        7.40132        .477552        .980060E-01    1.33795
TKN               6   .780000        1.64000        1.24000        1.20983        .266270        .273158        2.35687
TIP               6   .170000        .260000        .208333        .206196        .308306E-01    .412987        2.02646
AL                6   4.23000        4.23000        4.23000        4.22999        .286102E-05    1.00000        1.00000
FCOLI             6   290000.        405000.        357500.        355435.        37388.7        .591920        2.28333
```

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM          AUG 24, 1976          11112
                              ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 10)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               5   180.000       390.000       246.000       229.436       91.3717       .395807       1.73499
VSS               5   54.0000       125.000       90.8000       86.4577       27.6217       .662994E-01   1.40347
TS                0
VS                0
SETTS             5   .200000       1.50000       .700000       .537027       .485798       .596608       1.82204
BOD5              5   27.0000       64.0000       44.6000       42.2499       14.0656       .420175E-01   1.47360
COD               5   22.0000       27.0000       24.4000       24.3461       1.62481       .179052       2.26860
TOC               5   17.0000       61.0000       43.4000       39.7454       15.4609       .627881       2.10590
O&G               0
PH                5   6.80000       7.20000       7.04000       7.03839       .149666       .343551       1.84091
TKN               5   1.05000       1.32000       1.16000       1.15643       .923039E-01   .653096       2.24742
TIP               5   .310000       .360000       .332000       .331560       .172046E-01   .395895       1.99456
AL                5   3.46000       5.77000       4.54000       4.46544       .821389       .133721       1.72272
FCOLI             5   650000.       .102000E 07   834000.       821102.       145134.       .507779E-01   1.36365
                              ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 11)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               4   104.000       136.000       122.000       120.879       16.7162       .328393       1.49678
VSS               4   48.0000       77.0000       59.0000       57.9912       11.2916       .692864       1.90256
TS                0
VS                0
SETTS             4   .700000       1.30000       .950000       .923704       .229128       .498785       1.76191
BOD5              4   22.0000       34.0000       26.2500       25.8612       4.71036       .847697       2.05436
COD               0
TOC               4   11.0000       22.0000       17.2500       16.7207       4.02337       .505253       1.95043
O&G               0
PH                4   7.70000       8.10000       7.84999       7.84857       .150000       .888967       2.18530
TKN               4   2.20000       3.20000       2.70000       2.66025       .412311       .119583E-06   1.22145
TIP               4   .300000       .330000       .310000       .309764       .122474E-01   .816497       2.00000
AL                4   .000000       .000000       .000000       .000000       .000000       .000000       .000000
FCOLI             4   255000.       615000.       438750.       414916.       160061.       .523966E-01   1.42880
                              ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 12)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              22   76.0000       144.000       114.000       112.063       20.1269       .499681       2.15002
VSS              22   34.0000       86.0000       56.0909       54.3984       13.7969       .266983       1.09905
TS                0
VS                0
SETTS            22   .600000       1.20000       .818181       .806396       .143452       .890355       3.68814
BOD5             21   17.0000       138.000       36.1429       32.5220       23.8173       3.68023       15.9710
COD               0
TOC              22   15.0000       39.0000       22.3636       21.4403       6.75913       .829662       2.65810
O&G               0
PH               17   6.60000       7.00000       6.75882       6.75777       .119108       .626048       2.67699
TKN              22   2.20000       4.00000       3.09545       3.06357       .440534       .336470E-01   2.42016
TIP              22   .350000       23.3000       3.82272       1.03451       6.48505       1.70448       4.64205
AL               22   .000000       .000000       .327272       .000000       .333278       .350710       1.52721
FCOLI            22   330000.       .180000E 07   894545.       606066.       395247.       .477306       2.35440

                              ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 13)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              14   89.0000       191.000       123.857       119.967       32.6489       .833817       2.42248
VSS              14   51.0000       108.000       71.8571       70.0760       16.5523       .696741       2.43072
TS                0
VS                0
SETTS            14   .700000       4.10000       1.52143       1.40501       .755152       2.71391       9.83308
BOD5             14   64.0000       119.000       81.2143       79.9711       15.3212       1.51055       4.15137
COD               0
TOC              13   31.0000       76.0000       50.5385       48.6621       13.9814       .407937       1.81915
O&G               7   46.4000       112.000       66.3999       63.9633       19.9657       1.48897       4.08105
PH               13   6.60000       7.30000       7.00000       6.99655       .218386       .443076       2.40110
TKN              13   4.60000       7.05000       5.66922       5.58532       .937824       .387971       2.74460
TIP              13   .270000       1.10000       .690769       .643218       .239822       .102068       2.05498
AL               11   .000000       .000000       .000000       .000000       .000000       .000000       .000000
FCOLI             7   215000.       .125500E 07   615000.       541608.       311528.       .906678       2.98924
                              ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 14)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              10   157.000       200.000       201.200       199.710       23.9825       .343235       2.22723
VSS              10   56.0000       80.0000       68.5000       67.8887       9.03609       .176879       1.89824
TS                0
VS                0
SETTS             4   1.30000       2.20000       1.80000       1.76066       .367424       .211682       1.38156
BOD5             10   63.0000       96.0000       84.4000       83.9227       8.51117       1.28877       4.44696
COD               0
TOC               5   60.0000       87.0000       73.4000       72.7015       10.0916       .297062E-01   1.88294
O&G               5   27.6000       36.8000       33.5200       33.3302       3.46318       .746402       1.96616
PH                5   7.70000       7.90000       7.77999       7.77963       .748330E-01   .343813       1.88703
TKN               5   4.40000       4.70000       4.56000       4.55885       .101980       .271082       1.95560
TIP               5   .480000       1.58000       .874000       .790200       .405887       .755202       2.12177
AL                5   1.20000       2.40000       1.68000       1.61713       .466476       .363177       1.62803
FCOLI             0
```

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM          AUG 25, 1976          08152

                    ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 15)

 PARAMETER   POINTS   MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               7  20.0000       50.0000       35.4286       34.6687       7.53766       .638834       2.50716
VSS               7  4.00000       14.0000       7.42857       6.64722       3.49927       .600940       2.21360
TS                0
VS                0
SETTS             3  .100000       .200000       .133333       .125992       .471405E-01   .707108       1.50000
BOD5              7  18.0000       45.0000       31.8571       30.4042       9.28021       .998443E-01   1.61223
COD               0
TOC               3  25.0000       38.0000       31.3333       30.8812       5.31246       .938740E-01   1.50000
O&G               4  5.60000       12.4000       9.00000       8.63324       2.50599       .363590E-05   1.70088
PH                3  7.50000       7.50000       7.50000       7.49998       .000000       .000000       .000000
TKN               3  2.80000       4.80000       4.10000       3.98258       .920145       .700848       1.50000
TIP               3  .130000       .250000       .200000       .192650       .509902E-01   .528003       1.50000
AL                3  1.20000       1.40000       1.33333       1.32988       .942808E-01   .707107       1.50000
FCOLI             4  219000.       .184000E 07   716000.       517659.       569197.       .785860       1.97302
                    ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 16)

 PARAMETER   POINTS   MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               8  62.0000       102.000       75.6250       74.5042       13.3972       .665539       2.26695
VSS               8  17.0000       44.0000       27.8750       26.6355       6.50643       .543459       2.20571
TS                0
VS                0
SETTS             3  .200000       .300000       .266667       .262074       .471404E-01   .707106       1.50000
BOD5              8  16.0000       46.0000       33.0000       27.7351       11.6512       .265072       1.45812
COD               0
TOC               8  15.0000       38.0000       28.0000       26.8744       7.56637       .197380       1.86915
O&G               4  11.6000       17.6000       14.3000       14.0707       2.56710       .133002       1.19780
PH                8  6.90000       7.20000       6.98750       6.98688       .927025E-01   1.19157       3.74921
TKN               8  1.80000       4.90000       3.21250       2.98805       1.20461       .283446       1.48282
TIP               8  .230000       .580000       .368750       .346152       .131476       .402367       1.61315
AL                8  1.70000       3.30000       2.62500       2.56629       .528559       .511067       1.86224
FCOLI             4  36000.0       285000.       131750.       101519.       93298.9       .809479       2.11849
                    ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 17)

 PARAMETER   POINTS   MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               9  20.0000       289.000       74.4444       50.9790       80.3134       2.01056       5.72385
VSS               9  2.00000       189.000       40.0000       17.5952       55.9821       1.99144       5.64837
TS                0
VS                0
SETTS             3  .100000       .700000       .300000       .191293       .282843       .707107       1.50000
BOD5              9  50.0000       99.0000       66.5555       64.7578       16.1390       .752098       2.26819
COD               0
TOC               9  10.0000       69.0000       33.2222       28.7465       17.5105       .727472       2.55744
O&G               8  68.4000       89.6000       76.7333       76.3968       7.33727       .491934       2.11355
PH                9  6.90000       7.30000       7.08888       7.08771       .128620       .105609       1.98918
TKN               9  3.50000       6.70000       5.01111       4.87164       1.15513       .108797       1.53549
TIP               9  .100000       .400000       .230000       .211161       .866942E-01   .181544       2.44391
AL                9  2.10000       3.70000       2.96888       2.93284       .550658       .399769       2.02923
FCOLI             3  123000.       .111000E 07   536000.       371316.       418715.       .519916       1.50000

                    ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 18)

 PARAMETER   POINTS   MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               8  39.0000       75.0000       57.2500       55.6001       13.3299       .233488       1.38939
VSS               8  9.00000       20.0000       13.8750       13.4089       3.62069       .322195       1.84191
TS                0
VS                0
SETTS             3  .100000       .100000       .100000       .100000       .000000       .000000       .000000
BOD5              8  12.0000       31.0000       20.8750       19.7369       7.00781       .390944       1.56705
COD               0
TOC               8  23.0000       32.0000       26.7500       26.5590       3.23071       .358646       1.60339
O&G               3  22.0000       150.800       73.3333       51.5449       60.8406       .564958       1.50000
PH                8  4.70000       6.60000       5.46250       5.40777       .788887       .090261       1.34437
TKN               8  2.50000       6.40000       3.98750       3.71812       1.53821       .558278       1.61139
TIP               8  .430000       1.25000       .876250       .810325       .315196       .313567       1.48515
AL                8  8.00000       22.4000       15.1750       14.0968       5.47671       .947120E-01   1.40107
FCOLI             5  .000000       25500.0       14200.0       .000000       8812.48       .386708       1.94306
                    ROCHESTER CSO PP --- PERFORMANCE DATA --- FLOC-SED EFFLUENT (STORM # 19)

 PARAMETER   POINTS   MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               5  36.0000       96.0000       63.8000       59.2114       20.8491       .295571       1.28056
VSS               5  12.0000       30.0000       18.6000       17.5964       6.62119       .750502       2.03299
TS                0
VS                0
SETTS             2  .100000       .100000       .100000       .100000       .000000       .000000       .000000
BOD5              5  9.80000       13.0000       11.3200       11.2448       1.29368       .152695       1.36165
COD               0
TOC               5  5.00000       18.0000       12.8000       11.6951       4.66476       .523480       2.00818
O&G               4  50.0000       56.4000       52.0000       51.9381       2.57682       1.06044       2.25550
PH                5  6.50000       7.00000       6.81999       6.81750       .183303       .685745       2.22952
TKN               5  1.10000       1.40000       1.20000       1.19520       .109505       .912888       2.50002
TIP               5  .180000       .620000       .332000       .294202       .169399       .739778       1.92301
AL                5  6.40000       14.0000       10.3400       9.8544        3.18550       .127963       1.31153
FCOLI             0
```

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM          AUG 26, 1976          11:15

                        ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFL.  (STORM # 01)

 PARAMETER    POINTS    MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------- ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS                6  60.0000       274.000       148.000       134.575       64.1275       .818700       3.08087
VSS                6  15.0000       42.0000       25.8333       24.3931       8.93339       .657080       2.24858
TS                 0
VS                 0
SETTS              0
BOD5               3  6.60000       14.0000       10.8667       10.3502       3.12552       .096229       1.50000
COD               15  4.00000       12.0000       5.86667       5.48945       2.36267       1.37250       3.85925
TOC               15  6.00000       58.0000       22.4000       18.6221       13.6470       1.05809       3.64538
O&G                6  .000000       23.0000       12.5000       .000000       9.84462       .163503       1.20365
PH                15  5.85000       6.20000       6.03333       6.03242       .104350       .257339       2.36303
TKN               15  .000000       .800000       .266666       .000000       .249444       .819421       2.58138
TIP               15  .300000E-01   .190000       .873332E-01   .755262E-01   .448921E-01   .576661       2.72746
AL                 0
FCOLI              0

                        ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFL.  (STORM # 02)

 PARAMETER    POINTS    MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------- ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS                0
VSS                0
TS                 0
VS                 0
SETTS              0
BOD5               0
COD                9  7.00000       38.0000       25.3333       22.1315       11.2250       .292500       1.60236
TOC                9  23.0000       84.0000       48.8889       44.9788       20.0745       .607129       2.13100
O&G                5  20.0000       34.0000       29.6000       29.0575       5.27636       .959381       2.39536
PH                 5  5.70000       6.00000       5.78000       5.77884       .116619       1.15000       2.66010
TKN                9  1.20000       5.30000       2.44444       2.18863       1.23650       1.18381       3.44538
TIP                9  .170000       .620000       .274444       .250655       .136309       1.72150       4.72450
AL                 0
FCOLI              0

                        ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFL.  (STORM # 03)

 PARAMETER    POINTS    MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------- ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               18  28.0000       490.000       151.444       112.269       118.064       1.32748       4.28330
VSS               18  8.00000       350.000       79.5000       50.1438       81.3355       2.02920       7.10701
TS                18  89.0000       691.000       227.389       192.217       148.597       1.72028       5.73436
VS                18  4.00000       334.000       73.5555       36.2480       81.4111       1.83902       6.24496
SETTS             18  .200000       23.5000       4.00000       1.93678       5.46408       2.57086       9.28541
BOD5              18  12.0000       210.000       46.5889       32.7540       48.2211       2.27086       7.71696
COD                0
TOC               18  6.00000       123.000       28.3333       17.8997       25.7638       3.05052       12.0116
O&G                9  7.00000       51.0000       29.8889       24.8242       14.8507       .150807       1.99212
PH                 9  5.60000       6.20000       5.92222       5.91923       .187248       .222242       1.93695
TKN               18  .200000       4.40000       1.38889       .870578       1.23328       .949068       2.81403
TIP               18  .760000E-01   .810000       .257222       .201708       .194302       1.37659       4.16010
AL                 0
FCOLI              0

                        ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFL.  (STORM # 04)

 PARAMETER    POINTS    MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------- ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS                8  52.0000       336.000       144.500       124.045       83.3412       1.21562       3.79130
VSS                8  32.0000       112.000       68.8750       64.0787       25.1865       .232928       1.91911
TS                 0
VS                 0
SETTS              0
BOD5               0
COD                0
TOC                0
O&G                0
PH                 0
TKN                0
TIP                0
AL                 0
FCOLI              0

                        ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFL.  (STORM # 05)

 PARAMETER    POINTS    MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------- ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS                8  72.0000       359.000       141.875       124.843       86.0558       1.87584       5.16208
VSS                8  68.0000       304.000       126.500       112.955       71.0194       1.80506       4.98845
TS                 0
VS                 0
SETTS              0
BOD5               8  60.0000       49800.0       7278.75       1302.18       16092.4       2.25610       6.11318
COD                8  31.0000       57.0000       41.8750       40.9991       8.69536       .392013       1.77625
TOC                8  43.0000       182.000       88.6250       82.2163       38.0524       1.59098       4.80663
O&G                0
PH                 0
TKN                8  3.20000       8.00000       5.15000       4.95625       1.45945       .676385       2.45080
TIP                8  .680000       3.70000       1.40500       1.14881       1.00856       1.46932       3.97686
AL                 0
FCOLI              0
```

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM          AUG 24, 1976          11115

                    ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFL.  (STORM # 06)

 PARAMETER    POINTS    MINIMUM       MAXIMUM        AVERAGE       GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------- ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               13   66.0000       328.000       161.846       139.231       66.8337       1.23118       4.19160
VSS               13   48.0000       136.000       77.1538       74.1958       23.1777       1.24652       3.78781
TS                 0
VS                 0
SETTS              4   1.00000       2.50000       1.62500       1.54003       .544862       .652024       2.09695
BOD5              13   5.00000       40.0000       15.6154       13.1639       9.84915       1.35830       3.86067
COD               13   22.0000       32.0000       26.3846       26.1800       3.34062       .517624       1.95921
TOC               13   11.0000       77.0000       38.1538       34.0358       17.3863       .561252       2.73449
O&G                0
PH                 0
TKN               13   1.70000       4.00000       2.43846       2.33418       .767151       .968693       2.39478
TIP               13   .360000       .770000       .536153       .519589       .135450       .383896       1.65768
AL                 0
FCOLI              0

                    ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFLUENT (STORM # 7A)

 PARAMETER    POINTS    MINIMUM       MAXIMUM        AVERAGE       GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------- ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS                3   212.000       272.000       246.667       245.109       25.3684       .502066       1.50000
VSS                3   108.000       144.000       121.333       120.319       16.1107       .074556       1.50000
TS                 0
VS                 0
SETTS              3   4.40000       7.10000       5.70000       5.65065       1.10252       .455133E-01   1.50000
BOD5               3   67.0000       80.0000       75.3333       75.0924       5.90668       .691934       1.50000
COD                3   45.0000       59.0000       51.3333       51.0125       5.79272       .333069       1.50000
TOC                3   47.0000       59.0000       52.6667       52.4385       4.92161       .203706       1.50000
O&G                0
PH                 0
TKN                3   4.20000       5.40000       4.86667       4.84028       .498888       .381799       1.50000
TIP                3   .530000       .700000       .600000       .595776       .725718E-01   .549444       1.50001
AL                 0
FCOLI              0

                    ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFLUENT (STORM # 7B)

 PARAMETER    POINTS    MINIMUM       MAXIMUM        AVERAGE       GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------- ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               11   15.0000       180.000       56.8182       41.3024       50.1068       1.41154       3.71107
VSS               11   3.00000       76.0000       20.6364       14.3753       20.1597       1.85538       5.37498
TS                 0
VS                 0
SETTS             12   .100000       3.00000       .833333       .359296       1.06406       1.23351       2.81002
BOD5              12   9.10000       43.0000       18.5250       15.7923       11.1390       .967767       2.58969
COD               12   15.0000       35.0000       22.0000       21.3430       5.61249       .868245       3.10053
TOC                9   4.00000       39.0000       16.1111       13.3760       9.79165       1.10797       3.68916
O&G                0
PH                 0
TKN               12   .100000       1.80000       .991666       .805015       .469855       .376601       2.40710
TIP               12   .140000       .250000       .179166       .175137       .388283E-01   .455899       1.68057
AL                 0
FCOLI              2   40.0000       63.0000       51.5000       50.1995       11.5036       .000000       1.00000

                    ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFL.  (STORM # 08)

 PARAMETER    POINTS    MINIMUM       MAXIMUM        AVERAGE       GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------- ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               26   110.000       512.000       278.538       249.789       126.350       .363911       1.76807
VSS               26   22.0000       220.000       88.5385       79.1379       49.2257       .705957       2.01607
TS                 0
VS                 0
SETTS             25   .800000       9.00000       3.46800       2.71887       2.29830       .762967       2.66932
BOD5              26   28.0000       221.000       85.9615       72.0187       51.5904       .870708       2.87088
COD                0
TOC               26   33.0000       95.0000       53.7692       51.7418       15.5051       .909337       3.23491
O&G                0
PH                26   7.10000       8.20000       7.81538       7.81198       .226479       .985178       4.67957
TKN               26   .000000       1.76000       .180384       .000000       .380257       2.88582       11.7367
TIP               24   .370000       4.26000       1.18750       .983787       .798317       2.71639       10.6599
AL                 0
FCOLI              0

                    ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFL.  (STORM # 09)

 PARAMETER    POINTS    MINIMUM       MAXIMUM        AVERAGE       GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------- ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS                8   129.000       240.000       188.750       184.555       38.3928       .333989       1.76551
VSS                8   60.0000       103.000       85.7500       84.7418       12.5973       .590657       2.85967
TS                 0
VS                 0
SETTS              8   .760000       2.10000       1.31250       1.22528       .485898       .460008       1.85867
BOD5               8   8.00000       33.0000       22.3750       20.7418       7.69896       .497886       2.44902
COD                8   14.0000       24.0000       18.3750       18.1525       2.86956       .319086       2.77369
TOC                8   20.0000       52.0000       33.8750       31.8886       11.6987       .385646       1.83050
O&G                0
PH                 8   6.90000       7.60000       7.33750       7.33350       .239465       .029600       2.14050
TKN                8   .680000       2.80000       1.47875       1.34304       .669111       .889743       2.82862
TIP                8   .220000       .990000       .396250       .369403       .243399       2.13304       9.78709
AL                 0
FCOLI              0
```

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM          AUG 24, 1976          11115
                   ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFL,  (STORM # 10)
PARAMETER    POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO, MEAN    STD DEVIATION  SKEWNESS     KURTOSIS
------------ ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS               4   116.000      710.000      329.750      259.852      231.011      .830120      2.04302
VSS               4   37.0000      275.000      132.250      102.338      90.2258      .638715      1.91414
TS                0
VS                0
SETTS             6   .100000      7.50000      2.26667      .882538      2.62086      1.11644      2.03470
BOD5              6   16.0000      120.000      42.8333      32.9763      35.9231      1.50616      3.64576
COD               6   11.0000      27.0000      16.1667      15.4844      5.17741      1.30967      3.38911
TOC               6   14.0000      88.0000      38.8333      30.3294      27.8293      .796456      1.96825
O&G               0
PH                2   7.60000      7.70000      7.65000      7.64983      .500002E-01  .000000      1.00000
TKN               6   1.10000      1.60000      1.22667      1.21422      .184270      1.22796      2.93889
TIP               6   .110000      .260000      .180000      .173106      .493268E-01  .103288      1.93263
AL                2   1.92000      1.92000      1.92000      1.92000      .000000      .000000      .000000
FCOLI             0
                   ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFLUENT (STORM # 11)
PARAMETER    POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO, MEAN    STD DEVIATION  SKEWNESS     KURTOSIS
------------ ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS               9   64.0000      480.000      193.778      149.347      141.676      .907803      2.42418
VSS               9   40.0000      176.000      89.0000      76.9890      48.9875      .731376      2.00917
TS                0
VS                0
SETTS             9   .400000      4.10000      1.81111      1.37446      1.25117      .557159      1.91541
BOD5              9   28.0000      62.0000      37.4444      36.0514      10.9454      1.05135      3.07069
COD               0
TOC               8   10.0000      55.0000      30.3750      26.2803      15.8109      .493827      1.80986
O&G               0
PH                0
TKN               9   1.30000      6.00000      2.47777      2.23674      1.32479      1.93290      5.67849
TIP               9   .190000      .310000      .265555      .262321      .397523E-01  .657220      2.88167
AL                0
FCOLI             0
                   ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFLUENT (STORM # 12)
PARAMETER    POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO, MEAN    STD DEVIATION  SKEWNESS     KURTOSIS
------------ ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS              24   85.0000      526.000      186.000      164.061      105.794      1.63644      5.23543
VSS              24   40.0000      197.000      85.5000      76.9050      42.5598      1.14776      3.18292
TS                0
VS                0
SETTS            24   .800000      6.00000      2.46666      2.08714      1.46286      .959507      2.65623
BOD5             24   30.0000      137.000      53.7500      45.7211      26.8410      1.70474      5.27086
COD               0
TOC              24   3.00000      74.0000      36.8750      31.3430      17.0717      .200416      2.62713
O&G               0
PH                0
TKN              24   1.50000      3.60000      2.40000      2.34244      .533654      .504450      2.53371
TIP              24   .000000      .280000      .866665E-01  .000000      .832998E-01  .937003      2.49484
AL                0
FCOLI             0
                   ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFLUENT (STORM # 13)
PARAMETER    POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO, MEAN    STD DEVIATION  SKEWNESS     KURTOSIS
------------ ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS              14   204.000      366.000      253.286      249.691      45.1306      1.21773      3.58200
VSS              14   80.0000      209.000      120.714      116.436      35.0131      1.31092      3.75836
TS                0
VS                0
SETTS            14   1.00000      17.0000      5.04286      3.69350      4.52086      1.64086      4.48296
BOD5             14   29.0000      102.000      58.7143      54.5923      26.2690      2.16503      7.41822
COD               0
TOC              14   48.0000      111.000      65.7857      63.5167      19.2990      1.52326      3.91530
O&G               0
PH                0
TKN              14   4.78000      8.47000      6.73428      6.62326      1.20744      .339309E-01  1.73080
TIP              14   .610000      3.42000      1.83071      1.55251      1.00121      .472830      1.84398
AL                0
FCOLI             0
                   ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFLUENT (STORM # 14)
PARAMETER    POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO, MEAN    STD DEVIATION  SKEWNESS     KURTOSIS
------------ ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS              12   194.000      474.000      347.000      336.953      87.6594      .172962      2.22742
VSS              12   83.0000      219.000      148.917      143.412      38.8318      .165438      2.04869
TS                0
VS                0
SETTS             4   4.50000      7.50000      6.35000      6.21649      1.25200      .430696      1.55191
BOD5             12   54.0000      140.000      101.250      97.0809      27.1757      .417152      1.88956
COD               0
TOC              12   60.0000      155.000      103.250      99.4411      27.8661      .250667      1.95079
O&G               0
PH                0
TKN              12   3.90000      5.50000      4.61666      4.59202      .479293      .265018      2.16539
TIP              12   .300000      4.61000      1.00583      .706832      1.15201      2.50972      8.03151
AL                0
FCOLI             0
```

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM            AUG 25, 1976           08155

                      ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFLUENT (STORM # 15)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              12   116.000       740.000       361.000       302.160       212.886       .695338       2.11132
VSS              12   20.0000       467.000       153.083       97.0734       145.662       1.22543       3.09610
TS                0
VS                0
SETTS             4   4.50000       28.0000       13.7000       10.9976       8.67384       .711891       2.02030
BOD5             12   20.0000       322.000       94.1667       60.9474       100.045       1.57323       3.82408
COD               0
TOC              12   35.0000       380.000       128.250       87.4479       122.066       1.25194       2.94085
O&G               0
PH                0
TKN              12   1.80000       9.30000       3.04166       2.48886       2.34963       1.80089       4.81065
TIP              12   .600000       3.37000       1.65333       1.36880       .990263       .562520       1.82277
AL                0
FCOLI             0

                      ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFLUENT (STORM # 16)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               9   168.000       328.000       245.333       239.652       51.9679       .233600       1.76652
VSS               9   42.0000       124.000       67.0000       62.5973       26.5246       1.06901       2.84762
TS                0
VS                0
SETTS             3   6.00000       8.00000       6.66667       6.60384       .942808       .707108       1.50000
BOD5              9   12.0000       62.0000       30.4444       25.6750       17.9574       .710401       1.97794
COD               0
TOC               4   27.0000       84.0000       45.0000       40.3605       22.9456       1.03254       2.22792
O&G               0
PH                0
TKN               4   1.30000       4.00000       2.30000       2.04753       1.11580       .529096       1.67098
TIP               4   .770000       1.84000       1.45000       1.36967       .480624       .575099       1.72561
AL                0
FCOLI             0
                      ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFLUENT (STORM # 17)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               9   75.0000       405.000       177.556       140.087       116.460       1.08684       2.51586
VSS               9   57.0000       275.000       122.333       101.544       82.4351       1.10985       2.65922
TS                0
VS                0
SETTS             3   4.50000       20.0000       9.66667       7.39662       7.30677       .707107       1.50000
BOD5              9   69.0000       260.000       131.000       113.282       76.6101       1.02809       2.39510
COD               0
TOC               9   15.0000       154.000       83.4444       67.6688       46.3635       .673568E-01   1.69003
O&G               0
PH                0
TKN               9   3.40000       7.60000       4.56666       4.42305       1.25786       1.44584       3.98062
TIP               9   .210000       1.88000       .725555       .613199       .456242       1.55541       4.79688
AL                0
FCOLI             0

                      ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFLUENT (STORM # 18)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              12   88.0000       168.000       111.750       109.288       25.3118       1.29261       3.29389
VSS              12   26.0000       92.0000       50.4167       46.7595       20.0560       .696451       2.28862
TS                0
VS                0
SETTS             4   1.40000       6.00000       3.22500       2.66445       1.91099       .380565       1.49232
BOD5             12   33.0000       96.0000       60.5000       56.8594       23.0308       .571570       1.60662
COD               0
TOC              12   18.0000       71.0000       38.1667       33.4915       18.5330       .285118       1.67375
O&G               0
PH                0
TKN              12   1.50000       7.70000       3.01666       2.51365       2.01983       1.21332       3.02858
TIP              12   .280000       .610000       .427500       .412900       .114900       .520327       1.72002
AL                0
FCOLI             0

                      ROCHESTER CSO PP --- PERFORMANCE DATA --- GRIT-SWIRL EFFLUENT (STORM # 19)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------

NO DATA EXISTS FOR THIS REQUEST
```

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM              AUG 24, 1976          11118
                         ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFL.  (STORM # 01)

PARAMETER    POINTS   MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               6   81.0000       220.000       131.333       122.483       40.5771       .721829       2.08956
VSS               6   19.0000       164.000       71.1667       53.8560       49.4045       .732235       2.48347
TS                0
VS                0
SETTS             0
BODS              0
COD              15   5.00000       23.0000       12.0000       10.6486       5.87651       .589350       1.94955
TOC              15   8.00000       42.0000       20.8000       18.0809       10.4834       .376512       1.94123
O&G               6   4.00000       17.0000       11.5000       10.3836       4.46281       .368146       1.94920
PH               15   5.55000       6.10000       5.90333       5.89977       .203688       .326108       2.59257
TKN              15   .100000       1.20000       .533333       .391695       .351504       .486775       2.42651
TIP              15   .500000E-01   .220000       .986665E-01   .873175E-01   .528982E-01   1.15837       3.06571
AL                0
FCOLI             0
                         ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFL.  (STORM # 02)

PARAMETER    POINTS   MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               0
VSS               0
TS                0
VS                0
SETTS             0
BODS              0
COD               9   12.0000       35.0000       23.6667       22.2453       7.61577       .285919       1.95730
TOC               9   30.0000       53.0000       43.5555       42.9209       7.16645       .458309       2.09127
O&G               5   23.0000       47.0000       34.4000       33.4534       8.01490       .186546       2.06637
PH                5   5.70000       6.10000       5.85999       5.85848       .135646       .750156       2.36401
TKN               9   1.40000       6.00000       3.10444       2.89886       1.77145       .478752       1.54599
TIP               9   .190000       .790000       .382222       .332319       .211753       .825277       2.10551
AL                0
FCOLI             0
                         ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFL.  (STORM # 03)

PARAMETER    POINTS   MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              18   36.0000       195.000       91.2222       80.6733       47.5202       1.00174       2.77097
VSS              18   12.0000       115.000       35.7222       27.9335       30.6028       1.77648       4.55023
TS               18   80.0000       388.000       198.278       181.155       81.1217       .569728       3.09283
VS               17   13.0000       140.000       56.7059       48.0757       31.4486       1.03760       4.00041
SETTS            18   .100000       2.10000       .905555       .756645       .470781       .552936       3.21835
BODS             18   9.70000       107.000       32.0833       24.6306       26.5005       1.60438       4.57584
COD               0
TOC              18   5.00000       33.0000       18.2222       16.6320       7.45769       .538764       2.59468
O&G               9   3.00000       50.0000       14.6667       11.2150       12.9672       2.11627       6.18011
PH                9   5.60000       6.20000       5.88888       5.88616       .179161       .167052       2.14280
TKN              18   .330000       6.00000       1.95000       1.26479       1.68069       1.18103       3.54813
TIP              18   .900000E-01   .970000       .379444       .313601       .238920       1.09656       3.30615
AL                0
FCOLI             0

                         ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFL.  (STORM # 04)

PARAMETER    POINTS   MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              10   14.0000       155.000       76.5000       56.5579       50.0768       .205868       1.60361
VSS               9   2.00000       56.0000       19.8888       12.1862       16.3986       .948367       3.10013
TS                0
VS                0
SETTS             0
BODS              0
COD               0
TOC               0
O&G               0
PH                0
TKN               0
TIP               0
AL                0
FCOLI             0
                         ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFL.  (STORM # 05)

PARAMETER    POINTS   MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               7   108.000       184.000       137.714       135.252       26.2608       .335882       2.08999
VSS               7   96.0000       172.000       123.429       120.857       25.9607       .633018       2.17608
TS                0
VS                0
SETTS             0
BODS              7   180.000       33600.0       5991.43       1739.15       11295.9       2.02258       5.12580
COD               7   33.0000       46.0000       40.0000       39.7235       4.65986       .144007       1.48944
TOC               7   55.0000       104.000       74.5714       73.1918       14.7924       .734004       2.74758
O&G               0
PH                0
TKN               7   3.50000       5.30000       4.34285       4.29303       .665168       .323815       1.88807
TIP               7   .750000       2.95000       1.23714       1.09892       .721936       1.78511       4.68619
AL                0
FCOLI             0
```

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM          AUG 24, 1976          11:18

                     ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFL.  (STORM # 06)

 PARAMETER   POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO. MEAN   STD DEVIATION   SKEWNESS     KURTOSIS
------------ ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS              13  8.00000      124.000      48.7692      35.5482      35.7042      .891042      2.85673
VSS              12  4.00000      84.0000      30.3333      20.3117      24.7363      .944869      2.82592
TS                0
VS                0
SETTS             4  1.00000      2.00000      1.50000      1.41421      .500000      .000000      1.00000
BODS             13  8.00000      24.0000      15.3846      14.6650      4.79644      .519462      2.08475
COD              13  24.0000      35.0000      29.2308      29.0301      3.60031      .336810E-01  2.05701
TOC              13  17.0000      57.0000      35.2308      33.5600      10.9906      .596673      2.51765
O&G               0
PH                0
TKN              13  1.40000      3.60000      2.39230      2.30305      .646245      .168825      1.94167
TIP              13  .390000      .670000      .518461      .509516      .966233E-01  .209805      1.70187
AL                0
FCOLI             0
                     ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFLUENT (STORM # 7A)

 PARAMETER   POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO. MEAN   STD DEVIATION   SKEWNESS     KURTOSIS
------------ ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS               4  200.000      864.000      375.000      300.721      282.593      1.14817      2.32812
VSS               4  88.0000      524.000      204.000      147.069      184.889      1.14958      2.32935
TS                0
VS                0
SETTS             4  1.80000      48.0000      13.6250      6.66898      19.8480      1.15416      2.33292
BODS              4  35.0000      360.000      134.500      89.5771      131.047      1.10872      2.30179
COD               4  40.0000      86.0000      63.7500      61.2373      17.3548      .983050E-01  1.58240
TOC               4  54.0000      470.000      160.250      96.4517      178.861      1.15368      2.33253
O&G               0
PH                0
TKN               4  5.30000      7.10000      5.95000      5.91317      .683740      .950274      2.21377
TIP               4  .420000      .760000      .619999      .605856      .124700      .661383      2.05789
AL                0
FCOLI             0
                     ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFLUENT (STORM # 7B)

 PARAMETER   POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO. MEAN   STD DEVIATION   SKEWNESS     KURTOSIS
------------ ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS              12  30.0000      124.000      62.4167      55.6867      30.2805      .717779      2.30404
VSS              12  13.0000      63.0000      26.6667      23.2431      15.0236      1.27976      3.46330
TS                0
VS                0
SETTS            12  .100000      2.70000      .725000      .326201      .869026      1.20158      2.96675
BODS             12  9.00000      52.0000      21.9167      18.3053      14.1330      1.12607      2.88713
COD              12  17.0000      37.0000      22.5833      22.0236      5.45371      1.42923      4.45071
TOC              12  6.00000      52.0000      18.5000      14.9460      13.4505      1.39680      3.74587
O&G               0
PH                0
TKN              12  .300000      2.10000      1.10000      .937628      .580229      .470965      2.14715
TIP              12  .160000      .340000      .211666      .204491      .584295E-01  .902875      2.51453
AL                0
FCOLI             0

                     ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFL.  (STORM # 08)

 PARAMETER   POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO. MEAN   STD DEVIATION   SKEWNESS     KURTOSIS
------------ ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS              27  106.000      300.000      209.481      198.703      63.9868      .175928      1.66078
VSS              27  28.0000      116.000      68.1852      63.1943      25.4370      .171259      1.75710
TS                0
VS                0
SETTS            27  .100000      2.70000      1.76296      1.55250      .647587      .556208      2.71387
BODS             27  30.0000      98.0000      67.2592      64.0234      19.8673      .116567      1.85884
COD              27  35.0000      209.000      99.2963      83.9084      57.8226      .669363      1.92766
TOC              27  18.0000      94.0000      55.3333      50.0791      22.2976      .658096E-01  1.91792
O&G               0
PH               27  6.80000      8.00000      7.66296      7.65828      .261262      1.56143      5.55325
TKN              27  1.50000      4.60000      2.95925      2.86138      .731987      .330705E-02  2.82608
TIP              27  .140000      1.02000      .450740      .410757      .194896      .935845      3.84756
AL                0
FCOLI             0
                     ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFL.  (STORM # 09)

 PARAMETER   POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO. MEAN   STD DEVIATION   SKEWNESS     KURTOSIS
------------ ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS               8  166.000      265.000      211.375      209.350      29.2999      .224423      2.35968
VSS               8  60.0000      105.000      88.3750      87.0900      14.2998      .732869      2.37041
TS                0
VS                0
SETTS             8  .800000      1.80000      1.10000      1.07262      .284949      .153098      1.62900
BODS              8  17.0000      30.0000      23.3750      22.8677      4.84607      .738298E-01  1.41462
COD               8  8.00000      18.0000      11.7500      11.3084      3.30719      .531310      2.18667
TOC               8  14.0000      37.0000      22.5000      21.2237      7.84219      .622803      2.13849
O&G               0
PH                8  7.40000      7.60000      7.47499      7.47493      .829155E-01  .493559      1.62821
TKN               8  .730000      2.33000      1.42125      1.31312      .544665      .243880      1.85505
TIP               8  .000000      .210000      .103750      .000000      .830567E-01  .522999E-01  1.17454
AL                0
FCOLI             0
```

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM               AUG 24, 1976           11118
                          ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFL.  (STORM # 10)

PARAMETER    POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               6    79.0000       340.000       204.000      175.809       104.157       .215481       1.44571
VSS               6    36.0000       115.000       75.5000      68.5181       30.8045       .668984E-01   1.38782
TS                0
VS                0
SETTS             6    .500000       2.00000       1.28333      1.13163       .592780       .355643E-01   1.38835
BOD5              6    17.0000       42.0000       26.8333      24.8570       10.8845       .620449       1.48722
COD               6    13.0000       26.0000       17.1667      16.5661       4.81024       .849857       2.18198
TOC               6    13.0000       37.0000       22.5000      20.9623       8.46069       .459015       1.91687
O&G               0
PH                2    7.80000       7.90000       7.85000      7.84983       .500002E-01   .000000       1.00000
TKN               6    1.10000       2.10000       1.53667      1.48682       .407049       .569955       1.51529
TIP               6    .150000       .350000       .206666      .197488       .687184E-01   1.34953       3.27443
AL                0
FCOLI             0
                          ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFLUENT (STORM # 11)

PARAMETER    POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               9    74.0000       174.000       116.778      113.475       35.5083       .242119       1.59476
VSS               9    30.0000       89.0000       50.2222      47.1056       19.1298       .995666       2.62216
TS                0
VS                0
SETTS             9    1.50000       3.60000       2.70000      2.60810       .666666       .366492       1.88955
BOD5              9    16.0000       44.0000       25.5555      24.1489       8.42102       1.01401       2.98326
COD               0
TOC               8    19.0000       46.0000       27.1250      25.7352       9.51890       1.08248       2.50074
O&G               0
PH                0
TKN               9    1.00000       2.60000       1.65555      1.57565       .527280       .541488       2.05629
TIP               9    .000000       .600000E-01   .155555E-01  .000000       .183209E-01   1.42802       4.06386
AL                0
FCOLI             0
                          ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFLUENT (STORM # 12)

PARAMETER    POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              24    82.0000       240.000       129.792      121.788       51.0016       1.27270       3.10533
VSS              24    32.0000       152.000       66.6667      58.3895       36.6829       1.05199       2.86784
TS                0
VS                0
SETTS            24    .400000       2.60000       1.68750      1.56171       .588297       .829524E-01   2.39390
BOD5             24    13.0000       64.0000       31.9583      29.6075       12.5116       .715974       3.00268
COD               0
TOC              24    7.00000       61.0000       28.9167      26.0604       12.7930       .703584       2.98527
O&G               0
PH                0
TKN              24    .900000       3.60000       2.30000      2.17846       .708872       .371783E-01   2.22717
TIP              24    .000000       .260000       .103750      .000000       .100905       .648766       1.61716
AL                0
FCOLI             0

                          ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFLUENT (STORM # 13)

PARAMETER    POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              14    137.000       171.000       154.071      153.712       10.5591       .323778       1.76226
VSS              14    48.0000       72.0000       60.1429      59.8428       5.95047       .107970       2.86187
TS                0
VS                0
SETTS            14    .100000       1.10000       .285714      .218635       .250306       2.32122       8.11650
BOD5             14    22.0000       83.0000       41.9286      39.6305       15.0260       1.28520       4.47298
COD               0
TOC              14    33.0000       59.0000       43.0000      42.3374       7.78597       .608611       2.12238
O&G               0
PH                0
TKN              14    5.68000       9.42000       7.49928      7.40368       1.19785       .138691       1.68899
TIP              14    1.14000       3.00000       2.15643      2.03610       .683756       .257894       1.35789
AL                0
FCOLI             0
                          ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFLUENT (STORM # 14)

PARAMETER    POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN    STD DEVIATION    SKEWNESS       KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              12    163.000       350.000       265.833      260.128       52.6859       .382008       2.26191
VSS              12    65.0000       140.000       107.167      104.005       25.1225       .191092       1.85125
TS                0
VS                0
SETTS             4    1.70000       5.10000       2.90000      2.61579       1.36931       .739060       1.91740
BOD5             12    63.0000       92.0000       79.5000      79.0739       8.07775       .364276       2.65752
COD               0
TOC              12    31.0000       98.0000       71.8333      68.2008       20.7960       .516576       2.12643
O&G               0
PH                0
TKN              12    3.70000       6.80000       5.19166      5.11817       .882668       .517542E-01   2.30559
TIP              12    .240000       2.68000       .821666      .652898       .650884       1.05911       5.73251
AL                0
FCOLI             0
```

```
O'BRIEN & GERE ENGINEERS, INC.           LABORATORY DATA SYSTEM           AUG 25, 1976         08159

                      ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFLUENT (STORM # 15)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION    SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              12   61.0000       157.000       114.417       109.849       30.6670       .251999       1.93400
VSS              12   17.0000       70.0000       38.4167       32.1034       13.4936       1.20996       4.44803
TS                0
VS                0
SETTS             4   .800000       3.20000       2.07500       1.75492       .967923       .453744       1.82031
BOD5             12   16.0000       90.0000       37.1667       31.7640       22.7809       1.18596       3.07412
COD               0
TOC              12   15.0000       50.0000       34.5000       33.0156       9.54376       .468780E-01   2.67366
O&G               0
PH                0
TKN              12   .700000       8.70000       3.25000       2.30223       2.80134       1.04010       2.46045
TIP              12   .620000       2.26000       1.61583       1.50366       .544470       .457802       1.82043
AL                2   95.0000       189.000       142.000       133.996       47.0000       .000000       1.00000
FCOLI             0
                      ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFLUENT (STORM # 16)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION    SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               9   80.0000       185.000       140.111       135.902       32.2609       .502842       2.08321
VSS               8   30.0000       58.0000       43.1250       41.8082       10.6235       .128695       1.40479
TS                0
VS                0
SETTS             3   2.70000       4.60000       3.86667       3.76585       .833999       .639104       1.50000
BOD5              9   11.7000       36.0000       20.1889       18.1938       9.66777       .612285       1.61922
COD               0
TOC               4   24.0000       42.0000       32.7500       31.7961       7.05414       .299921E-01   1.10270
O&G               0
PH                0
TKN               4   1.60000       4.50000       2.65000       2.40015       1.19269       .594131       1.74801
TIP               4   .450000       .900000       .707500       .680021       .190181       .219873       1.29735
AL                0
FCOLI             0
                      ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFLUENT (STORM # 17)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION    SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              10   57.0000       284.000       138.400       121.580       73.0933       .660055       2.33950
VSS              10   40.0000       204.000       98.5000       79.6525       58.0969       .877634       2.12394
TS                0
VS                0
SETTS             4   2.50000       12.0000       5.55000       4.48604       4.85130       .948142       2.14017
BOD5             10   67.0000       223.000       121.400       110.401       54.7196       .731184       2.01601
COD               0
TOC              10   14.0000       160.000       41.8000       33.9123       28.0741       1.13818       3.43593
O&G               0
PH                0
TKN              10   2.80000       8.40000       4.98999       4.73995       1.69437       1.02753       2.83830
TIP              10   .170000       .970000       .524999       .461844       .249289       .313829       1.94407
AL                0
FCOLI             0

                      ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFLUENT (STORM # 18)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION    SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS              11   76.0000       98.0000       88.5454       88.3107       6.25755       .362332       2.30620
VSS              11   28.0000       52.0000       38.5454       37.1522       10.2102       .138187E-01   1.38017
TS                0
VS                0
SETTS             4   .300000       .400000       .325000       .322372       .433013E-01   1.15471       2.33333
BOD5             11   38.0000       81.0000       53.8182       51.2135       17.0977       .411316       1.56036
COD               0
TOC              11   20.0000       105.000       37.0000       32.9154       22.6756       2.35985       7.41068
O&G               0
PH                0
TKN              11   1.50000       7.00000       3.32727       2.84014       1.91220       .717233       1.95664
TIP              11   .240000       .670000       .488181       .467922       .135433       .114189       1.69524
AL                0
FCOLI             0
                      ROCHESTER CSO PP --- PERFORMANCE DATA --- PRIM-SWIRL EFFLUENT (STORM # 19)

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION    SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------- ------------- ------------- -------------
TSS               6   58.0000       168.000       99.0000       91.7661       38.9487       .562916       2.05024
VSS               6   12.0000       48.0000       27.6667       24.9856       12.3513       .509091       1.85466
TS                0
VS                0
SETTS             2   1.00000       1.40000       1.20000       1.18322       .200000       .000000       1.00000
BOD5              6   13.0000       38.0000       26.3333       24.6256       9.06764       .683038E-01   1.53560
COD               0
TOC               6   13.0000       29.0000       18.6667       18.0073       5.24934       .942009       2.83543
O&G               0
PH                0
TKN               6   .900000       2.50000       1.66667       1.57163       .561743       .298818       1.69369
TIP               6   .160000       .260000       .205000       .201789       .359390E-01   .182016E-04   1.77253
AL                0
FCOLI             0
```

APPENDIX C
Statistical Analysis of Influent and Effluent Data
Microscreen System

Reproduced from
best available copy.

Note: Concentrations of all parameters except pH and SETTS are expressed as mg/l. SETTS concentrations are expressed as ml/l.

STORM #12 - 03/03/76

INFLUENT -- ROCHESTER CSO PILOT PLANT -- FMC DATA

PARAMETER	POINTS	MINIMUM	MAXIMUM	AVERAGE	GEO. MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
AL	20	.000000	2.40000	.780000	.000000	.572363	.599790	4.14353
BUDS	19	22.0000	264.000	102.368	82.5904	66.4485	.950541	2.91556
CL-H	20	300.000	1404.00	599.500	543.568	289.865	1.38269	4.30510
PH	20	6.40000	7.00000	6.64499	6.64180	.206095	.311332	1.98125
SETTS	20	1.00000	5.00000	2.67500	2.48365	1.03096	.724954	3.00761
TC	20	32.0000	104.000	53.1000	51.1577	15.4722	1.51340	6.37626
TDS	20	369.000	2400.00	1064.85	972.249	463.507	1.00084	4.20748
TIC	20	15.0000	28.0000	20.6000	20.2507	3.83927	.412054	2.24096
TIP	20	.700000E-01	18.9000	3.31450	1.14402	5.59021	2.08677	5.84208
TKN	20	2.20000	6.10000	3.67999	3.55761	1.02742	1.25404	3.53427
TOC	20	13.0000	76.0000	32.5000	29.6438	14.4482	1.21554	4.78067
TS	20	829.000	2963.00	1381.50	1306.05	512.281	1.62301	5.49087
TSS	20	102.000	706.000	316.650	261.195	193.587	.675189	2.07204
VDS	14	4.00000	229.000	102.000	72.2852	56.9962	.101331	3.08818
VS	20	147.000	469.000	232.250	221.637	78.5658	1.58162	5.00203
VSS	19	42.0000	543.000	194.789	145.834	146.474	1.02810	2.99167

EFFLUENT -- ROCHESTER CSO PILOT PLANT -- FMC DATA

PARAMETER	POINTS	MINIMUM	MAXIMUM	AVERAGE	GEO. MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
BODS	20	26.0000	66.0000	44.1500	42.6341	11.5986	.292574	1.92597
SETTS	20	.500000	2.10000	.959999	.872660	.466261	1.30471	3.33796
TC	20	34.0000	89.0000	64.6000	63.3941	11.8085	.356076	3.80773
TIC	20	13.0000	25.0000	19.1500	18.7840	3.69154	.235666E-01	1.79271
TIP	20	.290000	.600000	.421500	.413622	.810723E-01	.166041	2.32153
TKN	20	2.60000	4.80000	3.45499	3.41688	.524657	.690495	3.17363
TUC	20	12.0000	71.0000	45.4500	43.2406	12.1593	.423056	4.51938
TSS	20	98.0000	317.000	157.650	147.630	63.6569	1.41295	3.76480
VSS	20	40.0000	123.000	65.9000	62.3036	23.7800	1.15870	3.23386

STORM # 13 - 03/12/76

INFLUENT --- ROCHESTER CSO PILOT PLANT -- FMC DATA

PARAMETER	POINTS	MINIMUM	MAXIMUM	AVERAGE	GEO. MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
AL	3	.000000	.000000	.000000	.000000	.000000	.000000	.000000
BOD5	3	70.0000	168.000	115.000	107.960	40.4063	.289223	1.50000
CL-M	3	151.000	176.000	167.333	166.158	20.3361	.686644	1.50000
O&G	1	86.0000	86.0000	86.0000	85.9999	.000000	.000000	.000000
PH	3	6.50000	7.00000	6.80000	6.79651	.216025	.595134	1.49497
SETTS	3	4.50000	18.5000	11.0000	9.40720	5.75905	.255224	1.50000
TC	3	75.0000	146.000	98.6667	93.6463	33.4697	.707107	1.50000
TDS	3	454.000	748.000	559.000	544.355	133.918	.694088	1.50000
TIC	3	25.0000	38.0000	30.6667	30.2023	5.43650	.431047	1.50000
TIP	3	.560000	.660000	.630000	.627871	.509902E-01	.527995	1.49999
TKN	3	4.31000	5.44000	4.90666	4.88439	.463489	.202413	1.50000
TOC	3	46.0000	105.000	68.0000	62.8612	28.3314	.696550	1.50000
TS	3	613.000	1096.00	813.333	788.971	205.599	.536465	1.50000
TSS	3	138.000	346.000	254.333	236.944	87.2175	.372277	1.50000
VDS	3	7.00000	139.000	63.3333	34.9827	55.5957	.479569	1.50000
VS	3	134.000	363.000	229.000	209.855	97.4713	.536120	1.50000
VSS	3	90.0000	224.000	165.667	154.518	56.0615	.434219	1.50000

EFFLUENT -- ROCHESTER CSO PILOT PLANT -- FMC DATA

PARAMETER	POINTS	MINIMUM	MAXIMUM	AVERAGE	GEO. MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
BOD5	3	107.000	110.000	109.000	108.990	1.41421	.707107	1.50000
O&G	2	75.2000	76.8000	76.0000	75.9956	.799995	.286387E-04	1.00000
SETTS	3	2.10000	4.90000	3.86667	3.61735	1.25521	.676933	1.50000
TC	3	114.000	133.000	121.667	121.398	8.17856	.582382	1.50000
TIC	3	32.0000	42.0000	35.6667	35.3973	4.49691	.680979	1.50001
TIP	3	.880000	1.15000	.996666	.990415	.113235	.451767	1.50000
TKN	3	5.92000	7.57000	6.53333	6.49360	.737126	.072046	1.50001
TOC	3	72.0000	101.000	86.0000	85.1838	11.8603	.125873	1.50000
TSS	3	200.000	220.000	212.333	212.147	8.80656	.646061	1.50000
VSS	3	103.000	125.000	114.333	114.018	8.37987	.445107	1.50000

STORM 17 - 05/11/76

INFLUENT -- ROCHESTER CSO PILOT PLANT -- FMC DATA

PARAMETER	POINTS	MINIMUM	MAXIMUM	AVERAGE	GEO. MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
AL	9	.000000	2.50000	1.01111	.000000	.623672	.632110	1.93242
BOD5	9	73.0000	319.000	134.222	118.235	76.6605	1.46067	3.90465
CL-M	9	58.0000	104.000	76.1111	74.9831	13.4614	.702531	2.73584
O&G	4	25.2000	59.2000	36.7000	34.4311	13.7996	.805846	1.99208
PH	9	6.60000	7.20000	6.84444	6.84215	.177082	.391899	2.68246
SETTS	3	3.90000	13.5000	7.66667	6.56926	4.24918	.528006	1.50000
TC	9	48.0000	164.000	100.889	92.4494	40.4102	.152109	1.53688
TDS	9	334.000	574.000	432.869	425.752	80.1805	.519388	2.10695
TIC	9	24.0000	36.0000	28.0000	27.6763	4.47214	1.07331	2.42533
TIP	9	.170000	1.53000	.632222	.501528	.421631	.954016	2.87506
TKN	9	2.10000	5.90000	3.38889	3.17706	1.29910	1.00261	2.48698
TOC	9	22.0000	128.000	72.9889	62.2822	36.7467	.295042E-01	1.46784
TS	9	448.000	945.000	611.889	592.223	165.301	.969053	2.50644
TSS	9	88.0000	395.000	179.000	148.959	118.435	1.06074	2.38438
VDS	9	58.0000	213.000	113.333	102.983	50.4777	.663657	2.17751
VS	9	112.000	406.000	213.111	190.298	107.502	.925324	2.30678
VSS	9	14.0000	250.000	99.7778	70.0217	83.6404	.977973	2.34238

EFFLUENT -- ROCHESTER CSO PILOT PLANT -- FMC DATA

PARAMETER	POINTS	MINIMUM	MAXIMUM	AVERAGE	GEO. MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
BOD5	6	187.000	246.000	202.333	201.449	19.8634	1.65323	3.96982
O&G	3	45.6000	56.8000	52.2000	51.9720	4.78609	.553840	1.49999
SETTS	2	6.00000	8.50000	7.25000	7.14142	1.25000	.000000	1.00000
TC	6	106.000	162.000	135.333	134.192	17.2691	.231051	2.37340
TIC	6	29.0000	49.0000	36.3333	35.8569	6.18241	1.12598	3.28150
TIP	6	1.04000	1.44000	1.24167	1.23342	.142410	.329673E-01	1.61012
TKN	6	6.00000	7.70000	6.66666	6.63794	.626276	.459746	1.70033
TOC	6	73.0000	127.000	99.0000	97.6800	16.0831	.173070	2.67654
TSS	6	240.000	400.000	318.000	314.476	47.0213	.121561	2.80541
VSS	6	136.000	250.000	191.333	188.406	33.1344	.147959	2.93444

Reproduced from best available copy.

APPENDIX D

Statistic Analysis of Effluent Data Dual Media Filters

Note: Concentrations of all parameters except pH are expressed as mg/l.

Dual Media Filter Influent Data

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM          OCT 26, 1976          16:40

                              ROCHESTER CSD P.P.  ---  SWINC DMFINC 10 GPM/SQFT

PARAMETER    POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO. MEAN    STD DEVIATION  SKEWNESS     KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS             59   16.0000      4612.00      131.508      58.7505      510.780      7.42768      56.4596
VSS             59   4.00000      68.0000      30.3220      26.6287      13.8618      .456080      3.15677
BOD5            55   3.00000      39.0000      17.1170      15.2999      8.08291      .687740      2.27673
TOC             43   5.00000      42.0000      20.6512      18.0004      8.66664      .624011      2.91969
COD             45   13.0000      73.0000      19.8139      18.7324      9.18354      4.50015      26.2786
O&G              0
TKN             43   .200000      5.00000      1.28837      .909606      1.14185      1.57696      4.39731
TIP             41   .500000E-01  .660000      .188048      .136866      .182050      1.65388      4.01780
PH              42   6.30000      7.50000      7.01664      7.01069      .285287      .598704      2.69248
AL              22   .400000      2.40000      .830363      .698192      .520003      1.16388      4.10900

                              ROCHESTER CSD P.P.  ---  SWINC DMFINC 15 GPM/SQFT

PARAMETER    POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO. MEAN    STD DEVIATION  SKEWNESS     KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS             49   16.0000      130.000      60.5506      56.0753      41.5098      .371236      1.32935
VSS             49   4.00000      82.0000      30.7755      26.6440      15.9492      1.17174      4.95418
BOD5            47   3.00000      65.0000      19.2468      16.0397      12.4835      1.60225      6.44066
TOC             31   8.00000      42.0000      19.1935      17.8110      7.81816      1.25742      4.42991
COD             27   13.0000      73.0000      18.7037      17.3354      11.0016      4.30672      21.4098
O&G              1   50.0000      50.0000      50.0000      50.0000      .000000      .000000      .000000
TKN             31   .400000      5.10000      1.20322      .907934      1.19609      2.21057      6.39270
TIP             31   .800000E-01  .320000      .133871      .123330      .654353E-01  1.99767      5.52297
PH              30   6.90000      7.50000      7.15999      7.15806      .164519      .701827E-01  2.12147
AL              10   .000000      1.30000      .480000      .000000      .355660      1.05352      3.86060

                              ROCHESTER CSD P.P.  ---  SWINC DMFINC 20 GPM/SQFT

PARAMETER    POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO. MEAN    STD DEVIATION  SKEWNESS     KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS             44   16.0000      4012.00      104.250      70.5818      587.000      6.36718      41.7089
VSS             44   8.00000      60.0000      33.9318      30.8983      13.6004      .378345      2.91289
BOD5            38   9.20000      39.0000      19.5737      17.7223      8.45708      .267193      1.64713
TOC             28   5.00000      41.0000      22.7857      20.7303      8.93371      .897049E-01  2.25920
COD             28   14.0000      73.0000      24.1071      20.7102      10.7049      3.78626      10.3163
O&G              0
TKN             28   .200000      5.00000      1.65000      1.19146      1.29766      .884052      2.55979
TIP             26   .560000E-01  .600000      .242692      .164028      .215487      .849492      1.97727
PH              28   6.30000      7.50000      6.84999      6.89385      .297609      .732219E-01  2.44564
AL              17   .400000      2.40000      1.01176      .856710      .550809      .610579      3.07056

                              ROCHESTER CSD P.P.  ---  SWINC DMFINC 25 GPM/SQFT

PARAMETER    POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO. MEAN    STD DEVIATION  SKEWNESS     KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS             33   14.0000      4012.00      171.608      53.6221      679.252      5.07093      30.9657
VSS             33   4.00000      68.0000      30.1515      25.0873      16.0060      .552875      2.68992
BOD5            27   3.00000      30.0000      13.4222      12.0900      5.05201      1.32822      5.97083
TOC             33   5.00000      82.0000      21.6360      19.5083      9.18106      .368835      2.89535
COD             33   13.0000      27.0000      18.0005      18.0567      3.97050      .690156      2.28022
O&G              0
TKN             33   .200000      9.00000      1.07879      1.03232      1.27011      1.07600      2.96583
TIP             31   .300000E-01  .660000      .221613      .153485      .203408      1.11008      2.51926
PH              32   6.30000      7.00000      6.90999      6.90356      .299800      .805621      2.00080
AL              23   .000000      2.40000      .869560      .723885      .936015      .981533      3.91089

                              ROCHESTER CSD P.P.  ---  SWINC DMFIPO 15 GPM/SQFT

PARAMETER    POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO. MEAN    STD DEVIATION  SKEWNESS     KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS             13   124.000      188.000      143.538      142.702      16.2462      1.51236      4.73137
VSS             13   28.0000      129.000      86.2308      82.4028      21.1778      1.10957      5.28167
BOD5             5   70.0000      90.0000      76.8000      76.0969      7.02967      1.07797      2.71212
TOC             13   19.0000      72.0000      39.2308      35.6903      17.0526      .560021      1.98806
COD              0
O&G              3   50.0000      60.0000      56.6667      56.4587      4.75908      .607633      1.50000
TKN             13   3.00000      4.90000      4.15380      4.10882      .579940      .939106      2.57918
TIP             13   .200000      .450000      .308615      .295037      .735090E-01  .120081      2.36692
PH              13   6.60000      7.00000      6.92307      6.91906      .211703      .619333      2.86088
AL              13   .000000      1.30000      .599000      .000000      .827870      .550290E-01  2.02377

                              ROCHESTER CSD P.P.  ---  SWIPO DMFINC 10 GPM/SQFT

PARAMETER    POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO. MEAN    STD DEVIATION  SKEWNESS     KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS             46   52.0000      388.000      216.022      203.379      68.0002      .425020      3.63680
VSS             45   6.00000      100.000      72.0222      61.9109      29.6678      .201536      2.76618
BOD5            47   6.00000      181.000      33.7007      26.7014      24.8560      1.81761      7.91833
TOC             47   2.00000      159.000      37.7021      32.4917      22.0935      3.00727      16.0328
COD             17   13.0000      56.0000      28.2901      26.4382      10.3122      1.22250      2.55917
O&G              0
TKN             44   [illegible]  6.70000      2.79886      .000000      2.03333      .590615      2.06550
TIP             40   [illegible]  21.2000      3.03016      .561785      5.63516      1.85632      9.08982
PH              45   [illegible]  7.90000      7.17330      7.16319      .380292      .873612E-01  1.75629
AL              35   [illegible]  26.5000      2.53182      .000000      4.24918      5.08937      28.9488
```

Dual Media Filter Influent Data

```
O'BRIEN & GERE ENGINEERS, INC.        LABORATORY DATA SYSTEM          OCT 26, 1976          10100
                                 ROCHESTER CSO P.P.  ---  SHIPO DMFINC 15 GPM/SQFT
PARAMETER    POINTS    MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN     STD DEVIATION  SKEWNESS       KURTOSIS
-----------  ------  ------------  ------------  ------------  ------------  ------------  ------------  ------------
TSS              35  52.0000       364.000       200.743       187.418       65.2354       .422253E-01   3.76289
VSS              36  4.00000       122.000       65.1176       54.6185       28.8706       .265504       2.38252
BOD5             36  7.00000       65.0000       29.9444       24.8969       18.2146       .440650       1.73480
TOC              36  2.00000       154.000       35.1055       29.0361       23.3021       1.54814       10.9622
COD              13  13.0000       21.0000       15.3077       15.1903       1.93687       1.78492       6.00508
O&G               0
TKN              33  .000000       6.60000       2.74545       .000000       2.20413       .461939       1.60525
TIP              37  .120000       21.2000       3.13053       .610032       5.68060       1.05092       5.14083
PH               36  6.60000       7.90000       7.81470       7.20511       .370319       .224250E-01   1.87065
AL               25  .000000       26.5000       3.14000       .000000       4.85946       4.40970       21.3781
                                 ROCHESTER CSO P.P.  ---  SHIPO DMFINC 20 GPM/SQFT
PARAMETER    POINTS    MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN     STD DEVIATION  SKEWNESS       KURTOSIS
-----------  ------  ------------  ------------  ------------  ------------  ------------  ------------  ------------
TSS              19  192.000       286.000       242.158       240.277       20.4122       .476889       2.04010
VSS              19  44.0000       122.000       82.7895       80.4762       19.1959       .124485       2.65404
BOD5             20  6.00000       141.000       33.0000       24.0064       31.0322       2.12821       7.57445
TOC              20  26.0000       154.000       47.0500       42.3916       27.6617       2.06620       11.4386
COD               4  51.0000       56.0000       53.5000       53.4694       1.80278       .000000       1.85207
O&G               0
TKN              20  1.55000       5.80000       2.30900       2.19900       1.11461       1.69160       5.19791
TIP              20  .100000       17.0000       3.24500       .671634       5.18013       1.45119       3.55962
PH               19  6.60000       7.80000       7.16841       7.15695       .405207       .266859E-02   1.49613
AL               18  .000000       3.20000       1.62778       .000000       1.01094       .245109       1.79472
                                 ROCHESTER CSO P.P.  ---  SHIPO DMFINC 25 GPM/SQFT
PARAMETER    POINTS    MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN     STD DEVIATION  SKEWNESS       KURTOSIS
-----------  ------  ------------  ------------  ------------  ------------  ------------  ------------  ------------
TSS              36  52.0000       364.000       211.083       196.503       67.9457       .384377       3.30068
VSS              35  4.00000       112.000       69.0000       57.0872       29.8142       .533629       2.27777
BOD5             36  6.00000       141.000       36.1111       28.8694       25.8070       1.86290       8.00754
TOC              36  2.00000       70.0000       35.1111       30.4470       15.7405       .207954       2.54419
COD              17  13.0000       56.0000       24.2941       20.4342       16.3122       1.22280       2.55917
O&G               0
TKN              33  .000000       6.60000       2.80090       .000000       2.09527       .443831       1.90943
TIP              37  .100000       21.2000       2.90000       .510528       5.91586       1.93960       5.22046
PH               35  6.60000       7.90000       7.10971       7.09670       .356926       .352000       8.06975
AL               27  .000000       26.5000       3.57037       .000000       6.83472       4.05686       22.2459
                                 ROCHESTER CSO P.P.  ---  SHIPO DMFIPO 10 GPM/SQFT
PARAMETER    POINTS    MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN     STD DEVIATION  SKEWNESS       KURTOSIS
-----------  ------  ------------  ------------  ------------  ------------  ------------  ------------  ------------
TSS               8  204.000       276.000       230.375       229.231       23.3235       .590957       2.32984
VSS               8  63.0000       80.0000       71.6250       71.3507       6.26373       .562205E-01   1.97079
BOD5              8  11.0000       14.0000       12.6250       12.5958       .850957       .391002       2.53372
TOC               8  21.0000       49.0000       38.3000       37.2580       9.08295       .560798       2.30107
COD               0
O&G               0
TKN               8  1.60000       3.75000       2.11375       2.02747       .604619       1.60122       4.20073
TIP               8  .210000       22.0000       6.74125       1.30833       8.56303       .607786       1.71211
PH                8  6.80000       8.00000       7.36250       7.35815       .387096       .155001       1.87509
AL                8  2.00000       3.20000       2.55000       2.52736       .362783       .341066       2.94374
                                 ROCHESTER CSO P.P.  ---  SWIAP DMFIPO 25 GPM/SQFT
PARAMETER    POINTS    MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN     STD DEVIATION  SKEWNESS       KURTOSIS
-----------  ------  ------------  ------------  ------------  ------------  ------------  ------------  ------------
TSS              17  114.000       249.000       169.765       161.099       55.2598       .596331       2.63777
VSS              17  26.0000       103.000       59.7059       54.0224       25.0711       .566921E-01   1.56405
BOD5              9  17.0000       84.0000       31.1111       29.0003       9.58522       .273106       1.92978
TOC              16  19.0000       230.000       49.2500       39.6721       60.0215       3.21479       12.5732
COD               0
O&G               5  16.0000       86.0000       37.0000       30.9220       25.3504       1.19790       2.85374
TKN              16  1.30000       8.33000       3.18870       2.75980       1.97048       1.96951       5.42000
TIP              16  .200000       14.7000       1.00500       .850905       3.39119       3.32911       13.6520
PH               14  3.10000       8.80000       6.51874       6.19032       1.11255       2.27096       6.31965
AL               16  7.70000       103.000       20.8819       17.0918       29.5860       2.26940       6.10954
                                 ROCHESTER CSO P.P.  ---  SWIAP DMFIAP 10 GPM/SQFT
PARAMETER    POINTS    MINIMUM       MAXIMUM       AVERAGE       GEO. MEAN     STD DEVIATION  SKEWNESS       KURTOSIS
-----------  ------  ------------  ------------  ------------  ------------  ------------  ------------  ------------
TSS              25  90.0000       326.000       160.320       152.980       50.5723       1.33940       4.02584
VSS              25  35.0000       135.000       59.1600       54.3670       27.9569       1.08343       5.67676
BOD5              3  20.0000       28.0000       23.3333       23.0799       3.39935       .520009       1.90000
TOC              25  36.0000       69.0000       46.6800       46.1750       6.89693       .109942       2.98650
COD               0
O&G               2  34.8000       34.0000       37.0000       37.1991       .000006       .000000       1.00000
TKN              25  1.40000       8.30000       5.09500       4.81703       1.73801       .832672       1.57632
TIP              25  .450000       2.14000       1.00050       .865561       .660206       .587402       1.01772
PH               25  6.00000       6.90000       5.60799       5.51019       1.56362       .807697       1.17286
AL               25  .000000       97.0000       15.6319       .000000       40.8595       .881929       1.24256
```

Dual Media Filter Influent Data

O'BRIEN & GERE ENGINEERS, INC.   LABORATORY DATA SYSTEM   OCT 26, 1976   16:31

ROCHESTER CSO P.P. --- SW1AP DMF1AP 20 GPM/SQFT

PARAMETER	POINTS	MINIMUM	MAXIMUM	AVERAGE	GEO. MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
TSS	4	172.000	212.000	191.250	192.627	19.4171	.167701	1.90107
VSS	4	75.0000	89.0000	80.0000	79.8154	5.52268	.001461	2.00000
BOD5	2	20.0000	23.0000	21.5000	21.4476	1.50000	.000000	1.00000
TOC	4	42.0000	66.0000	53.7500	53.0161	8.84217	.716621E-01	1.71300
COD	0							
O&G	1	80.8000	80.8000	80.8000	80.7999	.000000	.000000	.000000
TKN	3	8.20000	9.70000	8.93333	8.91233	.612826	.810903E-01	1.50000
TIP	4	2.19000	2.40000	2.26750	2.26610	.800280E-01	.842413	2.08743
PH	4	4.00000	4.10000	4.07500	4.07476	.433010E-01	1.15452	2.33305
AL	4	95.0000	97.0000	96.0000	95.9937	1.73205	1.19470	2.33333

ROCHESTER CSO P.P. --- SW1AP DMF1AP 25 GPM/SQFT

PARAMETER	POINTS	MINIMUM	MAXIMUM	AVERAGE	GEO. MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
TSS	3	142.000	260.000	209.667	205.725	36.3073	.709490	1.50000
VSS	3	78.0000	103.000	88.3333	85.5730	11.7051	.707107	1.50000
BOD5	3	28.0000	40.0000	35.3333	34.7292	5.39966	.294802	1.50000
TOC	2	42.0000	44.0000	43.0000	42.9802	1.00000	.000000	1.00000
COD	0							
O&G	1	86.0000	86.0000	86.0000	85.9999	.000000	.000000	.000000
TKN	2	8.05000	8.33000	8.18999	8.18879	.139999	.817124E-04	1.00000
TIP	2	1.25000	2.04000	1.64500	1.59687	.394999	.000000	1.00000
PH	2	3.10000	3.70000	3.40000	3.38674	.300000	.000000	1.00000
AL	2	95.0000	103.000	99.0000	98.9100	4.00000	.000000	1.00000

ROCHESTER CSO P.P. --- SW1PO DMF1PO 30 GPM/SQFT

PARAMETER	POINTS	MINIMUM	MAXIMUM	AVERAGE	GEO. MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
TSS	5	204.000	240.000	218.000	217.425	16.1988	1.00956	2.57678
VSS	5	63.0000	80.0000	70.4000	70.0895	6.65131	.265243	1.40669
BOD5	5	11.0000	13.0000	12.2000	12.1766	.748331	.343620	1.40694
TOC	5	30.0000	45.0000	37.8000	37.4449	5.11460	.135200	1.91576
COD	0							
O&G	0							
TKN	5	1.64000	2.50000	1.85600	1.82521	.366030	1.42254	3.13423
TIP	5	.210000	22.0000	7.48399	1.34078	9.16749	.595484	1.56796
PH	5	6.80000	7.80000	7.29999	7.29119	.357771	.785629E-01	1.60550
AL	5	2.40000	3.20000	2.72000	2.70302	.299332	.343625	1.40694

ROCHESTER CSO P.P. --- SW1PO DMF1PO 25 GPM/SQFT

PARAMETER	POINTS	MINIMUM	MAXIMUM	AVERAGE	GEO. MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
TSS	5	204.000	240.000	218.000	217.425	16.1988	1.00956	2.57678
VSS	5	63.0000	80.0000	70.4000	70.0895	6.65131	.265243	1.40669
BOD5	5	11.0000	13.0000	12.2000	12.1766	.748331	.343620	1.40694
TOC	5	30.0000	45.0000	37.8000	37.4449	5.11460	.135200	1.91576
COD	0							
O&G	0							
TKN	5	1.64000	2.50000	1.85600	1.82521	.366030	1.42254	3.13423
TIP	5	.210000	22.0000	7.48399	1.34078	9.16749	.595484	1.56796
PH	5	6.80000	7.80000	7.29999	7.29119	.357771	.785629E-01	1.60550
AL	5	2.40000	3.20000	2.72000	2.70302	.299332	.343625	1.40694

ROCHESTER CSO P.P. --- SW1PO DMF1AP 10 GPM/SQFT

PARAMETER	POINTS	MINIMUM	MAXIMUM	AVERAGE	GEO. MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
TSS	7	140.000	228.000	188.714	185.591	34.1873	.527380E-01	1.33837
VSS	7	20.0000	76.0000	39.4286	35.8753	17.9432	.948614	2.79787
BOD5	7	11.0000	13.0000	11.5714	11.5492	.728431	.859895	2.36391
TOC	7	21.0000	56.0000	35.0000	33.1271	11.6005	.416507	2.06605
COD	0							
O&G	0							
TKN	6	1.60000	2.90000	2.27500	2.23268	.435612	.133128	2.17590
TIP	6	.250000	21.2000	5.57499	1.49393	7.76066	1.20835	2.87027
PH	6	6.70000	7.70000	7.19999	7.19026	.374166	.439972E-04	1.50000
AL	7	.000000	2.80000	1.82857	.000000	.877845	1.06909	2.99303

ROCHESTER CSO P.P. --- SW1PO DMF1AP 20 GPM/SQFT

PARAMETER	POINTS	MINIMUM	MAXIMUM	AVERAGE	GEO. MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
TSS	7	140.000	228.000	188.714	185.591	34.1873	.527380E-01	1.33837
VSS	7	20.0000	76.0000	39.4286	35.8753	17.9432	.948614	2.79787
BOD5	7	11.0000	13.0000	11.5714	11.5492	.728431	.859895	2.36391
TOC	7	21.0000	56.0000	35.0000	33.1271	11.6005	.416507	2.06605
COD	0							
O&G	0							
TKN	6	1.60000	2.90000	2.27500	2.23268	.435612	.133128	2.17590
TIP	6	.250000	21.2000	5.57499	1.49393	7.76066	1.20835	2.87027
PH	6	6.70000	7.70000	7.19999	7.19026	.374166	.439972E-04	1.50000
AL	7	.000000	2.80000	1.82857	.000000	.877845	1.06909	2.99303

Dual Media Filter Influent Data

O'BRIEN & GERE ENGINEERS, INC.   LABORATORY DATA SYSTEM   OCT 26, 1976   16105

ROCHESTER CSO P.P. --- SW;PO DMF;AP 25 GPM/SQFT

PARAMETER	POINTS	MINIMUM	MAXIMUM	AVERAGE	GEO. MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
TSS	7	140.000	228.000	180.714	175.591	34.1873	.527380E-01	1.33037
VSS	7	20.0000	76.0000	39.4286	35.0753	17.9432	.948614	2.79787
BOD5	7	11.0000	13.0000	11.5714	11.5492	.728431	.859895	2.36391
TOC	7	21.0000	56.0000	35.0000	33.1271	11.6005	.436807	2.06605
COD	0							
O&G	0							
TKN	6	1.60000	2.90000	2.27500	2.23260	.435612	.133184	2.17990
TIP	6	.250000	21.2000	5.57499	1.49393	7.76066	1.20835	2.07027
PH	6	6.70000	7.70000	7.19999	7.19026	.374166	.430972E-04	1.50000
AL	7	.000000	2.00000	1.42857	.000000	.877845	1.06909	2.90303

ROCHESTER CSO P.P. --- SW;AP DMF;NC 15 GPM/SQFT

PARAMETER	POINTS	MINIMUM	MAXIMUM	AVERAGE	GEO. MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
TSS	58	31.0000	326.000	126.293	104.669	69.5141	.350897	2.54192
VSS	58	10.0000	134.000	49.4138	40.1840	28.0868	.413400	2.42910
BOD5	28	20.0000	34.0000	27.7857	27.6009	3.05143	.995683	4.32166
TOC	56	9.00000	66.0000	38.1296	34.1444	16.5849	.601086E-02	3.15867
COD	0							
O&G	5	18.4000	38.0000	28.6400	27.6138	7.58356	.785690E-01	1.42807
TKN	57	2.50000	8.30000	4.16842	3.94224	1.53081	1.29698	3.26797
TIP	58	.600000E-01	20.7000	1.81792	.849773	3.46081	4.31220	21.5409
PH	58	4.60000	9.10000	6.37986	6.28049	1.12277	1.29851	3.90278
AL	58	.000000	97.0000	16.5517	.000000	30.7861	1.73875	4.12120

ROCHESTER CSO P.P. --- SW;AP DMF;NC 20 GPM/SQFT

PARAMETER	POINTS	MINIMUM	MAXIMUM	AVERAGE	GEO. MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
TSS	4	172.000	212.000	193.250	192.627	15.4171	.167701	1.50167
VSS	4	75.0000	89.0000	80.0000	79.8154	5.52268	.801464	2.00000
BOD5	2	20.0000	23.0000	21.5000	21.4476	1.50000	.000000	1.00000
TOC	4	42.0000	66.0000	53.7500	53.0161	8.84237	.714621E-01	1.71304
COD	0							
O&G	1	40.8000	40.8000	40.8000	40.7999	.000000	.000000	.000000
TKN	3	8.20000	9.70000	8.93333	8.91283	.612826	.814503E-01	1.50000
TIP	4	2.19000	2.40000	2.26750	2.26610	.804208E-01	.842413	2.08743
PH	4	8.00000	8.10000	8.07500	8.07476	.433010E-01	1.15452	2.33305
AL	4	93.0000	97.0000	96.0000	95.9887	1.73205	1.15470	2.33333

ROCHESTER CSO P.P. --- SW;AP DMF;NC 25 GPM/SQFT

PARAMETER	POINTS	MINIMUM	MAXIMUM	AVERAGE	GEO. MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
TSS	41	31.0000	260.000	109.317	87.0670	60.0456	.475504	1.92007
VSS	41	10.0000	103.000	39.0732	31.2506	26.4092	.869578	2.60822
BOD5	31	14.0000	84.0000	28.6189	27.9308	6.13649	.283303	3.57719
TOC	37	9.00000	230.000	33.0216	26.8142	35.0569	4.71192	26.6537
COD	0							
O&G	6	21.6000	86.0000	36.4000	31.6791	22.7483	1.58751	3.82352
TKN	41	1.60000	8.33000	3.07463	2.86188	1.45631	2.31538	8.40576
TIP	42	.600000E-01	14.7000	.885988	.201984	2.25016	5.95033	37.5402
PH	42	5.10000	9.10000	6.99760	6.52902	.871578	2.19083	13.5011
AL	42	.000000	103.000	10.0190	.000000	20.6078	3.65769	15.9416

ROCHESTER CSO P.P. --- SW;AP DMF;PO 15 GPM/SQFT

PARAMETER	POINTS	MINIMUM	MAXIMUM	AVERAGE	GEO. MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
TSS	83	31.0000	326.000	128.389	98.3505	80.1650	.315089	1.93605
VSS	83	10.0000	134.000	50.3721	39.4429	33.0215	.313985	1.87085
BOD5	28	20.0000	34.0000	27.7857	27.6009	3.05143	.995683	4.32166
TOC	59	9.00000	86.0000	34.3590	31.0050	17.7550	.261697	2.42012
COD	0							
O&G	5	18.4000	38.0000	28.6400	27.6138	7.58356	.785690E-01	1.42807
TKN	82	2.50000	8.30000	4.33333	4.05418	1.74529	.915939	2.20888
TIP	83	.600000E-01	20.7000	1.71538	.816305	3.47592	3.61331	15.5561
PH	83	4.80000	9.10000	6.83255	6.80012	1.27073	.860722	2.79580
AL	83	.000000	97.0000	22.1678	.000000	33.9988	1.27133	2.71231

ROCHESTER CSO P.P. --- SW;AP DMF;PO 20 GPM/SQFT

PARAMETER	POINTS	MINIMUM	MAXIMUM	AVERAGE	GEO. MEAN	STD DEVIATION	SKEWNESS	KURTOSIS
TSS	4	172.000	212.000	193.250	192.627	15.4171	.167701	1.50167
VSS	4	75.0000	89.0000	80.0000	79.8154	5.52268	.801464	2.00000
BOD5	2	20.0000	23.0000	21.5000	21.4476	1.50000	.000000	1.00000
TOC	4	42.0000	66.0000	53.7500	53.0161	8.84237	.714621E-01	1.71304
COD	0							
O&G	1	40.8000	40.8000	40.8000	40.7999	.000000	.000000	.000000
TKN	3	8.20000	9.70000	8.93333	8.91283	.612826	.814503E-01	1.50000
TIP	4	2.19000	2.40000	2.26750	2.26610	.804208E-01	.842413	2.08743
PH	4	8.00000	8.10000	8.07500	8.07476	.433010E-01	1.15452	2.33305
AL	4	93.0000	97.0000	96.0000	95.9887	1.73205	1.15470	2.33333

Dual Media Filter Effluent Data

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM          OCT 26, 1976          09139
                                    ROCHESTER CSD P.P.  ---  SWING DMFINC 10 GPM/SQFT

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------ ------------- ------------- ------------
TSS              39  7.00000       89.0000       31.6410       25.3469      25.3078       .948160       2.60760
VSS              40  2.00000       52.0000       19.9750       16.5112      13.7671       1.09597       3.25456
BOD5              3  .000000       20.0000       6.66667       .000000      9.42809       .707107       1.50000
TOC              33  5.00000       33.0000       14.9485       13.3690      6.70406       .780850       3.00216
COD              33  8.00000       28.0000       19.0606       17.4811      4.60525       .575460       3.04751
O&G               0
TKN              33  .500000       3.00000       1.38788       1.10322      .923351       .811347       1.72064
TIP              32  .300000E-01   .800000       .175937       .131809      .142233       1.15593       2.05900
PH               32  6.40000       7.70000       7.04687       7.03791      .351767       .343036       1.95393
AL               19  .000000       1.60000       .326316       .000000      .390467       1.03456       4.05308
                                    ROCHESTER CSD P.P.  ---  SWING DMFINC 15 GPM/SQFT

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------ ------------- ------------- ------------
TSS              29  4.00000       93.0000       32.9655       24.5972      27.1324       1.25450       2.94053
VSS              29  .000000       37.0000       13.1720       .000000      8.57051       1.23352       6.08437
BOD5              6  7.60000       14.2000       11.0667       10.8099      2.62950       .169551       2.41110
TOC              17  5.00000       17.0000       13.1176       12.6735      2.90005       1.30782       4.91500
COD               5  11.0000       16.0000       14.0000       13.4467      2.05912       .131050       1.32093
O&G               3  51.2000       64.4000       56.1333       55.8379      5.88100       .660071       1.50000
TKN              17  .600000       24.7000       3.54706       2.12606      5.41295       3.46179       13.7426
TIP              16  .700000E-01   .290000       .193750       .174240      .790070E-01   .260452       1.55201
PH               16  6.70000       7.80000       7.16874       7.16698      .156990       1.51060       5.27524
AL               13  .000000       .400000       .307692E-01   .000000      .106588       3.17544       11.0833
                                    ROCHESTER CSD P.P.  ---  SWING DMFINC 20 GPM/SQFT

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------ ------------- ------------- ------------
TSS              36  9.00000       103.000       53.4639       38.9294      34.7669       .739644E-01   1.24000
VSS              36  3.00000       48.0000       22.4055       16.9221      14.2552       .165394       1.68092
BOD5              1  10.0000       10.0000       10.0000       10.0000      .000000       .000000       .000000
TOC              18  6.00000       31.0000       11.8333       10.3610      7.41006       1.88308       4.74381
COD              18  14.0000       27.0000       19.5000       18.2094      3.51589       1.28171       3.42725
O&G               0
TKN              18  .400000       3.10000       1.20555       1.03149      .773500       1.56390       3.99775
TIP              18  .400000E-01   .450000       .147222       .107920      .136943       1.56071       3.72421
PH               18  6.50000       7.50000       7.08333       7.07708      .275378       .592320       2.02460
AL                7  .000000       1.20000       .514285       .000000      .412063       .142013       1.85051
                                    ROCHESTER CSD P.P.  ---  SWING DMFINC 25 GPM/SQFT

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------ ------------- ------------- ------------
TSS              20  16.0000       76.0000       34.1000       31.3197      15.1087       1.29672       3.81551
VSS              20  5.00000       52.0000       20.4000       17.5326      12.2041       1.33115       3.60927
BOD5              4  .000000       20.0000       7.50000       .000000      8.29156       .493382       1.62810
TOC              20  5.00000       35.0000       18.0500       15.7065      8.72624       .210005       1.94010
COD              20  10.0000       32.0000       19.5000       18.0124      5.05470       .245069       3.26426
O&G               0
TKN              20  .400000       4.00000       1.81500       1.50560      1.17016       .277321       1.71390
TIP              18  .400000E-01   .510000       .220889       .151706      .172816       .147471       1.26262
PH               19  6.40000       7.50000       6.81052       6.80379      .305097       .730913       2.50054
AL               19  .000000       1.20000       .692631       .000000      .414680       .213539       1.67125
                                    ROCHESTER CSD P.P.  ---  SWING DMFIPU 15 GPM/SQFT

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------ ------------- ------------- ------------
TSS              25  17.0000       63.0000       29.5600       28.2219      10.0601       1.79058       6.05620
VSS              25  10.0000       40.0000       19.2800       18.0014      6.37193       1.52971       5.61725
BOD5             17  2.20000       11.8000       6.64705       6.04204      2.75769       .313203       2.04986
TOC              25  11.0000       27.0000       18.4400       18.0843      3.57060       .220185       3.21950
COD               0
O&G               6  42.8000       60.4000       53.6666       53.3691      5.43202       .902645       3.07735
TKN              25  2.40000       5.30000       3.51200       3.44780      .666525       .246298       3.59150
TIP              25  .140000       .320000       .238000       .233638      .490978E-01   .592782       2.61337
PH               25  6.70000       7.50000       7.02399       7.02186      .172696       .419244       3.50027
AL               25  .000000       .400000       .400000E-01   .000000      .129984       2.33874       6.46972
                                    ROCHESTER CSD P.P.  ---  SWIPO DMFINC 10 GPM/SQFT

 PARAMETER   POINTS    MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN   STD DEVIATION   SKEWNESS      KURTOSIS
------------ ------ ------------- ------------- ------------- ------------ ------------- ------------- ------------
TSS              47  10.0000       169.000       52.1489       45.7753      29.3301       1.96025       8.16375
VSS              47  1.00000       57.0000       17.7021       14.2560      11.2664       1.60088       6.59078
BOD5             24  3.70000       19.0000       8.40749       7.74796      4.03074       1.40978       3.83741
TOC              46  5.00000       77.0000       14.0217       11.3257      10.8730       3.46512       15.8081
COD              16  10.0000       51.0000       19.2500       17.0480      11.5731       1.90122       5.15622
O&G               0
TKN              45  .000000       5.20000       1.84755       .000000      1.53464       .956024       2.84587
TIP              46  .500000E-01   10.1000       1.55912       .327748      3.98459       3.06499       11.0190
PH               43  6.60000       8.00000       7.26277       7.25275      .379732       .267096E-02   2.01318
AL               43  .000000       11.6000       .709301       .000000      1.80784       5.14074       30.7367
```

Dual Media Filter Effluent Data

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM          OCT 26, 1976          09137
                                  ROCHESTER CSO P.P.  ---  SHIPO DMFINC 15 GPH/SQFT

PARAMETER   POINTS   MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS             20  16.0000      84.0000      35.4000      31.6815      18.1366      1.35193      3.83121
VSS             20  4.00000      31.0000      12.6300      11.0604      6.63754      1.07283      3.77392
BOD5            12  3.70000      8.00000      5.97490      5.70572      1.66066      .117824      1.60503
TOC             19  2.00000      17.0000      10.3158      8.30915      3.79821      .221182      2.37777
COD             11  12.0000      16.0000      13.7273      13.6759      1.21288      .838006      2.67499
O&G              0
TKN             16  .600000      4.30000      1.64000      1.41609      1.05076      1.73357      6.50284
TIP             20  .400000E-01  1.81000      .360000      .217309      .475520      2.09661      6.26190
PH              17  5.40000      8.00000      7.17647      7.14811      .603089      1.16237      6.30000
AL              16  .000000      22.7000      1.90000      .000000      5.60843      3.93116      13.6802
                                  ROCHESTER CSO P.P.  ---  SHIPO DMFINC 20 GPH/SQFT

PARAMETER   POINTS   MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS             17  46.0000      172.000      92.2941      85.9290      37.2968      .766872      2.26058
VSS             17  16.0000      64.0000      32.7059      30.1492      13.1765      .602042      2.36076
BOD5             6  13.0000      38.0000      20.3333      19.1069      8.13770      1.54960      3.02789
TOC             17  8.00000      29.0000      18.3520      17.2406      5.99901      .671798E-01  2.27216
COD              2  29.0000      31.0000      31.0000      30.9354      2.00000      .000000      1.00000
O&G              0
TKN             17  .940000      4.00000      1.90023      1.79125      .778102      1.02551      5.30093
TIP             17  .500000E-01  1.73000      .429990      .302612      .421838      2.06029      6.20223
PH              17  6.80000      7.60000      7.20238      7.27702      .864917      .526983      1.88550
AL              17  .000000      2.00000      .423529      .000000      .692420      .181523      1.86038
                                  ROCHESTER CSO P.P.  ---  SHIPO DMFINC 25 GPH/SQFT

PARAMETER   POINTS   MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS             15  23.0000      110.000      64.4667      57.7537      27.9496      .153044      1.88329
VSS             15  7.00000      40.0000      20.4667      17.6191      11.4105      .338551      1.64550
BOD5             9  3.70000      8.60000      6.99990      6.83789      1.32413      1.48713      4.59679
TOC             14  1.00000      30.0000      15.0714      11.8619      8.44701      .353839      2.08064
COD             11  13.0000      54.0000      24.9091      22.4228      16.0331      .736173      1.75000
O&G              0
TKN             15  1.00000      3.30000      1.67533      1.60042      .809687      .666625      1.66463
TIP             15  .700000E-01  1.00000      .309333      .196698      .421164      2.92227      10.5111
PH              15  6.10000      7.70000      6.96666      6.95364      .423740      .135870      2.70065
AL              15  .000000      .800000      .160000      .000000      .185459      .408246      1.16667
                                  ROCHESTER CSO P.P.  ---  SHIPO DMFIPO 10 GPH/SQFT

PARAMETER   POINTS   MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS              8  30.0000      114.000      80.0000      78.6791      26.9013      .550744      1.80451
VSS              8  .000000      34.0000      21.7500      .000000      11.0199      .784551      2.28917
BOD5             0
TOC              8  11.0000      24.0000      17.5000      17.0912      3.70810      .300393E-01  2.49554
COD              0
O&G              0
TKN              8  1.17000      2.50000      1.76250      1.72816      .376321      .753114      3.57132
TIP              8  .600000E-01  18.0000      1.62250      .369779      5.87023      2.21505      6.00190
PH               8  6.70000      8.00000      7.41250      7.40302      .355097      .504035      3.04077
AL               8  .000000      1.20000      .850000      .000000      .466369      .717206      1.79429
                                  ROCHESTER CSO P.P.  ---  SHIAP DMFIPO 25 GPH/SQFT

PARAMETER   POINTS   MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS             25  1.00000      118.000      23.2400      8.08912      30.0378      1.70089      4.80577
VSS             25  .400000      52.0000      9.90400      2.27971      10.6233      1.68968      4.92768
BOD5             3  18.8000      42.0000      28.3333      26.3122      11.8807      .705558      1.50000
TOC             23  9.00000      41.0000      15.2609      13.9907      7.45546      2.00489      6.85589
COD              0
O&G              8  9.20000      65.2000      19.7500      15.9880      17.6642      2.05938      5.50556
TKN             20  1.50000      8.33000      2.69666      2.39099      1.73861      2.66679      8.79269
TIP             20  .000000      1.80000      .332083      .000000      .420706      2.09293      5.98220
PH              23  3.50000      6.90000      5.89999      6.01500      .490039      2.03672      9.31113
AL              24  .000000      91.0000      7.96250      .000000      21.4452      3.02892      10.1060
                                  ROCHESTER CSO P.P.  ---  SHIAP DMFIAP 15 GPH/SQFT

PARAMETER   POINTS   MINIMUM       MAXIMUM       AVERAGE      GEO. MEAN    STD DEVIATION   SKEWNESS      KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS             16  10.0000      104.000      50.7318      42.0685      25.0154      .176096      2.51078
VSS             16  1.30000      82.0000      21.0500      15.9176      17.3297      .709018E-01  1.91781
BOD5             2  13.9000      21.9000      17.7000      17.1986      4.20000      .000000      1.00000
TOC             15  3.00000      39.0000      21.3333      19.0238      7.69992      .497869      3.07906
COD              0
O&G              0
TKN             15  2.20000      9.00000      2.85000      2.79289      1.31027      2.69481      9.80064
TIP             15  .600000E-01  .500000      .133333      .909880E-01  .141053      2.20793      6.92169
PH              15  6.20000      7.10000      6.67999      6.65557      .676461      3.23946      10.0695
AL              15  .000000      52.0000      3.97333      .000000      12.8403      3.67003      13.0528
```

Dual Media Filter Effluent Data

```
O'BRIEN & GERE ENGINEERS, INC.          LABORATORY DATA SYSTEM          OCT 26, 1976          16131
                                 ROCHESTER CSO P.P.  ---  SW/AP DMF/AP 20 GPM/SQFT
PARAMETER    POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO. MEAN    STD DEVIATION  SKEWNESS      KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS              3   23.5000      105.000      75.0333      62.5180      37.0062      .693291      1.50000
VSS              3   9.30000      40.0000      28.1000      23.5253      13.4494      .634513      1.50000
BOD5             0
TOC              3   20.0000      39.0000      32.6667      31.2166      8.95468      .707103      1.50000
COD              0
O&G              1   24.0000      24.0000      24.0000      24.0000      .000000      .000000      .000000
TKN              2   7.90000      8.70000      8.30000      8.29015      .400000      .321306E-08  1.00000
TIP              3   .420000      1.50000      1.15000      .987205      .510909      .673966      1.50000
PH               3   6.00000      6.20000      6.10000      6.09918      .816495E-01  .176798E-08  1.50000
AL               3   56.0000      93.0000      78.0000      76.2180      15.8955      .575162      1.50000
                                 ROCHESTER CSO P.P.  ---  SW/AP DMF/AP 25 GPM/SQFT
PARAMETER    POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO. MEAN    STD DEVIATION  SKEWNESS      KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS              2   72.0000      94.0000      83.0000      82.2478      11.0000      .000000      1.00000
VSS              2   32.0000      40.0000      36.0000      35.7770      4.00000      .000000      1.00000
BOD5             0
TOC              1   33.0000      33.0000      33.0000      33.0000      .000000      .000000      .000000
COD              0
O&G              1   40.0000      40.0000      40.0000      39.9999      .000000      .000000      .000000
TKN              1   8.05000      8.05000      8.05000      8.04999      .000000      .000000      .000000
TIP              1   1.20000      1.20000      1.20000      1.20000      .000000      .000000      .000000
PH               1   5.60000      5.60000      5.60000      5.60000      .000000      .000000      .000000
AL               1   87.0000      87.0000      87.0000      86.9999      .000000      .000000      .000000
                                 ROCHESTER CSO P.P.  ---  SW/PO DMF/PO 20 GPM/SQFT
PARAMETER    POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO. MEAN    STD DEVIATION  SKEWNESS      KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS              4   96.0000      146.000      119.000      117.066      21.0709      .101838      1.16721
VSS              4   33.0000      46.0000      40.2500      39.8894      5.21916      .418342      1.05580
BOD5             0
TOC              4   16.0000      27.0000      22.7500      22.2986      4.52200      .609262      1.79977
COD              0
O&G              0
TKN              4   1.17000      2.62000      1.76750      1.69401      .520269      .681086      2.10653
TIP              4   .110000      .360000      .270000      .220722      .172771      .949278      2.10740
PH               4   7.30000      7.90000      7.62500      7.62492      .291595E-01  .493165      1.62809
AL               4   1.20000      2.00000      1.60000      1.56919      .000000      .372529E-08  .999999
                                 ROCHESTER CSO P.P.  ---  SW/PO DMF/PO 25 GPM/SQFT
PARAMETER    POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO. MEAN    STD DEVIATION  SKEWNESS      KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS              5   78.0000      174.000      123.400      119.485      31.5886      .212152      2.17631
VSS              5   24.0000      51.0000      35.4000      34.0371      10.0519      .445719      1.62254
BOD5             0
TOC              5   18.0000      37.0000      25.0000      24.1412      6.84105      .734630      2.23263
COD              0
O&G              0
TKN              5   1.26000      2.58000      1.87200      1.82187      .435586      .200265      2.19388
TIP              5   .190000      26.1000      5.55195      .753329      10.2789      1.49604      3.24514
PH               5   7.00000      7.50000      7.27400      7.27338      .193987      .379106      1.40006
AL               5   1.20000      2.00000      1.60000      1.55922      .397771      .418900E-08  1.89000
                                 ROCHESTER CSO P.P.  ---  SW/PO DMF/AP 10 GPM/SQFT
PARAMETER    POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO. MEAN    STD DEVIATION  SKEWNESS      KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS              7   20.0000      92.0000      46.0571      39.8189      24.9572      .620984      1.72953
VSS              7   4.00000      20.0000      8.00000      6.82608      5.33723      1.57526      4.04668
BOD5             0
TOC              7   9.00000      32.0000      16.9714      15.0889      7.99438      .970870      2.71808
COD              0
O&G              0
TKN              7   1.37000      2.24000      1.82429      1.80909      .259307      .208918      2.41306
TIP              7   .150000      15.0000      2.70571      .582285      5.09788      1.92157      4.87269
PH               7   6.70000      7.60000      7.11429      7.10787      .309699      .582266E-01  1.76131
AL               7   .400000      1.60000      .857140      .767788      .388897      .549305      2.59938
                                 ROCHESTER CSO P.P.  ---  SW/PO DMF/AP 20 GPM/SQFT
PARAMETER    POINTS   MINIMUM      MAXIMUM      AVERAGE      GEO. MEAN    STD DEVIATION  SKEWNESS      KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS              7   38.0000      108.000      70.0000      66.1087      23.5672      .282985      2.20002
VSS              7   6.00000      26.0000      10.7143      9.06986      7.06529      1.39032      3.27359
BOD5             0
TOC              7   11.4000      33.0000      21.7143      20.3401      7.62916      .214060      1.64851
COD              0
O&G              0
TKN              7   1.56000      2.24000      1.79286      1.77901      .221599      .036003      2.71313
TIP              6   .700000E-01  .340000      .211666      .186919      .945897E-01  .319985E-01  1.74505
PH               7   6.80000      8.00000      7.37140      7.36397      .341067      .249746      2.01219
AL               7   .800000      3.20000      2.11429      1.97681      .666304      .457750      3.17790
```

Dual Media Filter Effluent Data

```
O'BRIEN & GERE ENGINEERS, INC.        LABORATORY DATA SYSTEM          OCT 26, 1976          16124
                                  ROCHESTER CSO P.P.  ---  SWIPO DMFIAP 25 GPM/SQFT
PARAMETER   POINTS    MINIMUM      MAXIMUM      AVERAGE     GEO. MEAN   STD DEVIATION   SKEWNESS     KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS             7    20.0000      144.000      93.7143      80.1050      41.3926      .888808      2.00611
VSS             7    9.00000      40.0000      21.5714      18.9524      10.8346      .520125      1.84900
BOD5            0
TOC             7    7.00000      34.0000      21.4286      19.4857      8.24373      .256311      2.23067
COD             0
O&G             0
TKN             7    1.37000      2.24000      1.96428      1.94597      .355726      .338362      2.57397
TIP             7    .300000E-01  1.23000      .410571      .227889      .355707      .975455      2.10853
PH              7    7.00000      7.80000      7.41428      7.40854      .289960      .352960      1.77458
AL              7    .800000      3.20000      2.40000      2.23371      .709124      1.30454      3.96280
                                  ROCHESTER CSO P.P.  ---  SWIAP DMFINC 15 GPM/SQFT
PARAMETER   POINTS    MINIMUM      MAXIMUM      AVERAGE     GEO. MEAN   STD DEVIATION   SKEWNESS     KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS            72    7.00000      178.000      56.8569      40.1028      40.3147      .975569      2.38749
VSS            72    2.00000      74.0000      23.0444      15.5505      20.9159      1.06630      2.59013
BOD5           25    6.90000      26.0000      18.0280      17.3779      4.40558      .492568      3.16481
TOC            60    .000000      51.0000      24.0215      .000000      11.5935      .417073      2.43061
COD             0
O&G             4    18.4000      31.6000      25.2000      24.3769      6.40624      .581702E-02  1.00770
TKN            71    2.00000      7.10000      3.69436      3.50989      1.36174      1.77366      4.65779
TIP            71    .800000E-01  1.91000      .497037      .317048      .306249      1.70428      6.70307
PH             71    4.00000      7.30000      6.48105      6.38129      1.01388      1.99987      5.03940
AL             72    .000000      89.0000      12.1888      .000000      27.1697      2.09205      5.48348
                                  ROCHESTER CSO P.P.  ---  SWIAP DMFINC 20 GPM/SQFT
PARAMETER   POINTS    MINIMUM      MAXIMUM      AVERAGE     GEO. MEAN   STD DEVIATION   SKEWNESS     KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS             4    75.0000      136.000      117.250      114.099      28.8130      1.08438      2.23628
VSS             4    28.0000      54.0000      44.2500      42.8000      10.2561      .672180      1.86128
BOD5            0
TOC             4    27.0000      48.0000      40.5000      39.5608      8.07775      .922073      2.16052
COD             0
O&G             1    26.8000      26.8000      26.8000      26.7999      .000000      .000000      .000000
TKN             4    7.50000      8.30000      7.82500      7.81951      .294768      .692004      2.06395
TIP             4    .950000      1.77000      1.54250      1.49506      .343465      1.12744      2.31072
PH              4    8.10000      8.30000      8.15000      8.14910      .866028E-01  1.15476      2.33342
AL              4    60.0000      89.0000      81.7500      80.6481      12.5574      1.15479      2.33333
                                  ROCHESTER CSO P.P.  ---  SWIAP DMFINC 25 GPM/SQFT
PARAMETER   POINTS    MINIMUM      MAXIMUM      AVERAGE     GEO. MEAN   STD DEVIATION   SKE NESS     KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS            51    7.00000      200.000      69.9863      52.8375      42.1558      .823038      3.18901
VSS            51    1.00000      95.0000      24.0000      18.2700      19.9685      1.21344      4.58005
BOD5           27    13.0000      31.0000      20.2000      19.4524      5.62763      .511377      2.08782
TOC            46    5.00000      45.0000      22.4565      20.2275      9.31269      .378738      3.20697
COD             0
O&G             8    .000000      25.2000      10.0000      .000000      7.38846      1.64605      4.66229
TKN            49    1.10000      8.52000      2.25959      2.06487      1.19581      3.13073      14.0388
TIP            49    .000000      1.67000      .265918      .000000      .264697      2.96448      16.4969
PH             49    3.70000      7.00000      6.52858      6.50737      .454007      4.85968      30.8540
AL             49    .000000      83.0000      6.97345      .000000      11.5935      5.71349      37.7771
                                  ROCHESTER CSO P.P.  ---  SWIAP DMFIPO 15 GPM/SQFT
PARAMETER   POINTS    MINIMUM      MAXIMUM      AVERAGE     GEO. MEAN   STD DEVIATION   SKEWNESS     KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS            35    2.00000      110.000      15.0771      7.73295      27.0819      3.70930      15.1586
VSS            35    .700000      45.0000      4.42857      2.26657      9.30374      3.74974      15.2689
BOD5           25    8.00000      26.1000      18.9720      17.1083      6.35115      1.42126      3.68649
TOC            30    1.00000      42.0000      14.7667      12.2674      8.55835      1.61065      6.03324
COD             0
O&G             4    9.60000      15.2000      12.3000      12.1995      2.21585      .810726E-01  1.36667
TKN            34    2.00000      7.50000      3.48235      3.35525      1.11526      2.49679      9.20751
TIP            35    .300000E-01  1.52000      .190289      .872783E-01  .330783      2.92849      10.7242
PH             34    3.80000      7.80000      6.64411      6.57220      .852397      2.56351      8.37568
AL             35    .000000      81.0000      8.63428      .000000      18.3146      3.01988      15.6042
                                  ROCHESTER CSO P.P.  ---  SWIAP DMFIPO 20 GPM/SQFT
PARAMETER   POINTS    MINIMUM      MAXIMUM      AVERAGE     GEO. MEAN   STD DEVIATION   SKEWNESS     KURTOSIS
----------- ------ ------------ ------------ ------------ ------------ ------------ ------------ ------------
TSS             4    22.5000      104.000      61.0000      47.6816      38.1650      .253783E-01  1.03448
VSS             4    8.10000      38.0000      21.6500      17.0102      13.5102      .726321E-01  1.09709
BOD5            0
TOC             4    20.0000      40.0000      30.2500      29.1295      8.07380      .494949E-01  1.29005
COD             0
O&G             1    20.0000      20.0000      20.0000      20.0000      .000000      .000000      .000000
TKN             3    7.40000      8.20000      7.83333      7.82631      .329983      .290756      1.49998
TIP             4    .210000      1.42000      .854999      .660019      .501223      .110926      1.23999
PH              4    8.10000      8.30000      8.15000      8.14910      .866028E-01  1.15476      2.33342
AL              4    48.3000      85.0000      69.0250      67.0861      17.5853      .956927      2.16622
```

Reproduced from
best available copy.

APPENDIX E
Chlorine and Chlorine Dioxide Analytical Data

Note: Concentrations of F.Coli are expressed as colonies/100 ml.

CL_2 AND CLO_2 ANALYTICAL DATA UTILIZED IN MULTIPLE REGRESSION ANALYSIS

CL_2 DATA

SAMP NO.	PREDICTED LOG KILL	OBSERVED LOG KILL	RESIDUAL	DOSE (MG/L)	D.T. (MIN)	GT	TEMP (C)	PH	TKN (MG/L)	BOD (MG/L)	TSS (MG/L)	VSS (MG/L)	INFLUENT F. COLI	EFFLUENT F. COLI
43727	2.47986	3.60649	-1.40663	3.1	5.6	89604.	7.0	8.0	1.4	15.0	183.0	74.0	385000.	50.
43727	2.31641	3.30670	-.99029	3.1	3.8	89527.	7.0	8.0	1.4	15.0	183.0	74.0	385000.	190.
43727	2.90654	4.28443	-1.37559	3.9	5.6	89604.	7.0	8.0	1.4	15.0	183.0	74.0	385000.	20.
43731	3.50014	6.57403	-3.07369	9.1	3.8	89527.	7.0	6.8	1.4	45.0	160.0	71.0	375000.	0.
43731	3.74711	3.61979	.12732	9.1	5.6	89604.	7.0	6.8	1.4	45.0	160.0	71.0	375000.	90.
49246	3.50631	3.60446	-.45665	8.9	1.5	67211.	8.0	7.3	2.1	19.0	65.0	22.0	184500.	20.
49246	3.96058	3.56702	.39356	8.9	3.0	67302.	8.0	7.3	2.1	19.0	65.0	22.0	184500.	50.
49246	4.25382	3.66393	.56929	8.9	4.5	67394.	8.0	7.3	2.1	19.0	65.0	22.0	184500.	40.
43928	2.77611	3.62942	-1.15131	6.2	1.1	53795.	5.0	7.2	1.1	6.0	45.0	12.0	170000.	20.
43928	3.13845	3.45250	-.31394	6.2	2.2	53893.	5.0	7.2	1.1	6.0	45.0	12.0	170000.	60.
43951	3.13469	4.34242	-1.20773	5.2	1.9	69451.	5.0	7.0	1.1	6.0	25.0	8.0	220000.	10.
43951	3.54031	4.34242	-.80211	5.2	3.8	69527.	5.0	7.0	1.1	8.0	25.0	6.0	220000.	10.
43733	2.03749	3.20242	-1.16493	5.5	1.9	69451.	9.0	6.8	1.2	55.0	304.0	120.0	1020000.	640.
43733	2.30113	3.30103	-.99990	5.5	3.8	69527.	9.0	6.6	1.2	55.0	304.0	120.0	1020000.	510.
43733	2.46350	3.39581	-.93232	5.5	5.6	69604.	9.0	6.8	1.2	55.0	304.0	120.0	1020000.	410.
43733	1.69340	3.92942	-2.23602	4.2	1.9	89451.	9.0	6.8	1.2	55.0	304.0	120.0	1020000.	120.
43733	1.91252	3.72984	-1.81733	4.2	3.8	89527.	9.0	6.8	1.2	55.0	304.0	120.0	1020000.	190.
43735	1.85859	3.55764	-1.69925	3.3	1.9	69451.	9.0	7.2	1.1	30.0	168.0	71.0	650000.	180.
43735	2.04656	3.17944	-1.00058	3.3	3.8	69527.	9.0	7.2	1.1	30.0	168.0	71.0	650000.	430.
43735	2.24696	3.90982	-1.66257	3.3	5.6	69504.	9.0	7.2	1.1	30.0	168.0	71.0	650000.	80.
43735	2.15756	3.73573	-1.57595	4.2	1.9	69451.	9.0	7.2	1.1	30.0	168.0	71.0	650000.	120.
43735	2.43710	3.55764	-1.12054	4.2	3.8	69527.	9.0	7.2	1.1	30.0	168.0	71.0	650000.	180.
43735	2.60907	3.77152	-1.16245	4.2	5.6	69604.	9.0	7.2	1.1	30.0	168.0	71.0	650000.	110.
49288	2.00670	3.57403	-1.56733	3.6	1.9	89451.	8.0	7.8	3.0	26.0	129.0	60.0	525000.	140.
49288	2.20656	4.02119	-1.75463	3.6	3.8	69527.	8.0	7.8	3.0	26.0	129.0	60.0	525000.	50.
49288	2.42628	4.41913	-1.99285	3.6	5.6	69504.	8.0	7.8	3.0	26.0	129.0	60.0	525000.	20.
49268	3.33771	3.04201	-.60429	7.8	1.9	69451.	8.0	7.8	3.0	26.0	129.0	60.0	525000.	60.
49268	3.76960	3.81707	-.04747	7.8	3.6	69527.	8.0	7.8	3.0	26.0	129.0	60.0	525000.	60.
49288	4.03559	3.94201	.09358	7.8	5.6	69604.	8.0	7.8	3.0	26.0	129.0	60.0	525000.	60.
49288	5.03172	4.01913	.61259	14.4	1.9	69451.	8.0	7.8	3.0	26.0	129.0	60.0	525000.	20.
49258	5.08251	4.72016	.96265	14.4	3.8	69527.	8.0	7.8	3.0	26.0	129.0	60.0	525000.	10.
49240	2.10527	3.32585	-1.22058	3.6	1.9	89451.	8.0	8.1	2.4	22.0	104.0	48.0	360000.	170.
49240	2.37769	4.25527	-1.87758	3.6	3.8	69527.	8.0	6.1	2.4	22.0	104.0	48.0	360000.	20.
49290	2.54546	3.77915	-1.23269	3.6	5.6	69604.	8.0	8.1	2.4	22.0	104.0	48.0	360000.	60.
49290	3.50167	3.65321	-.15154	7.8	1.9	89451.	8.0	8.1	2.4	22.0	104.0	48.0	360000.	80.
49290	3.95477	3.55630	.39847	7.8	3.6	89527.	8.0	8.1	2.4	22.0	104.0	48.0	360000.	100.
49290	4.23393	4.07918	.15465	7.8	5.6	89604.	8.0	8.1	2.4	22.0	104.0	48.0	360000.	30.
49561	2.58951	3.68425	-1.09444	7.8	1.9	89451.	7.0	6.8	2.2	51.0	112.0	68.0	870000.	180.
49561	3.13130	3.79339	-.66209	7.8	5.6	69604.	7.0	6.8	2.2	51.0	112.0	68.0	870000.	140.
49561	2.70984	3.59710	-.88725	8.3	1.9	89451.	7.0	6.8	2.2	51.0	112.0	68.0	870000.	220.
49561	3.06048	3.98528	-.92479	8.3	3.8	89527.	7.0	6.8	2.2	51.0	112.0	68.0	870000.	90.
49561	3.27643	3.61730	-.34087	8.3	5.6	89604.	7.0	6.8	2.2	51.0	112.0	68.0	870000.	210.
49561	3.54757	4.24055	-.59248	13.0	1.9	89451.	7.0	6.8	2.2	51.0	112.0	68.0	870000.	50.
49561	4.11955	2.97573	1.14382	13.0	3.8	89527.	7.0	6.8	2.2	51.0	112.0	68.0	870000.	420.
49561	4.41022	4.46240	-.05217	13.0	5.6	89604.	7.0	6.8	2.2	51.0	112.0	68.0	870000.	30.
49563	3.31892	3.60639	-.28756	7.8	1.9	89451.	7.0	6.7	2.6	27.0	128.0	64.0	1010000.	250.
49563	3.74826	3.41326	.33501	7.8	3.8	89527.	7.0	6.7	2.6	27.0	128.0	64.0	1010000.	390.
49563	4.01274	4.00432	.00842	7.8	5.6	89604.	7.0	6.7	2.6	27.0	128.0	64.0	1010000.	100.
49563	3.78361	3.30535	.47826	9.5	1.9	89451.	7.0	6.7	2.5	27.0	128.0	64.0	1010000.	500.
49563	4.27320	3.42453	.84867	9.5	3.8	89527.	7.0	6.7	2.6	27.0	128.0	64.0	1010000.	380.
49563	4.57472	3.74905	.82557	9.5	5.6	89604.	7.0	6.7	2.6	27.0	128.0	64.0	1010000.	180.

SAMP NO.	PREDICTED LOG KILL	OBSERVED LOG KILL	RESIDUAL	DOSE (MG/L)	D.T. (MIN)	GT	TEMP (C)	PH	TKN (MG/L)	BOD (MG/L)	TSS (MG/L)	VSS (MG/L)	INFLUENT F. COLI	EFFLUENT F. COLI
49563	4.95754	4.52720	.43034	14.2	1.9	89451.	7.0	6.7	2.6	27.0	128.0	64.0	1010000.	30.
49563	5.59904	3.77387	1.82516	14.2	3.8	89527.	7.0	6.7	2.6	27.0	128.0	64.0	1010000.	170.
49563	5.99411	4.70329	1.29081	14.2	5.6	89604.	7.0	6.7	2.6	27.0	128.0	64.0	1010000.	20.
49565	3.37582	3.19149	.18433	7.8	1.9	89451.	7.0	6.7	3.0	25.0	138.0	64.0	1220000.	785.
49565	3.81207	3.51816	.29393	7.8	3.8	89527.	7.0	6.7	3.0	25.0	138.0	64.0	1220000.	370.
49565	4.08156	4.48430	-.40263	7.8	5.6	89604.	7.0	6.7	3.0	25.0	138.0	64.0	1220000.	40.
49565	3.98458	2.53006	1.45463	10.0	1.9	89451.	7.0	6.7	3.0	25.0	138.0	64.0	1220000.	3600.
49565	4.50029	4.24126	.25903	10.0	3.8	89527.	7.0	6.7	3.0	25.0	138.0	64.0	1220000.	70.
49565	4.81783	3.65499	1.16284	10.0	5.6	89604.	7.0	6.7	3.0	25.0	138.0	64.0	1220000.	270.
49565	5.27917	3.83109	1.44808	15.3	1.9	89451.	7.0	6.7	3.0	25.0	138.0	64.0	1220000.	180.
49565	5.96227	3.68842	2.27385	15.3	3.8	89527.	7.0	6.7	3.0	25.0	138.0	64.0	1220000.	250.
49565	6.38298	4.38739	1.99559	15.3	5.6	89604.	7.0	6.7	3.0	25.0	138.0	64.0	1220000.	50.
49567	3.23469	3.69548	-.46079	7.1	1.9	89451.	7.0	6.8	3.4	25.0	126.0	70.0	1240000.	250.
49567	3.65324	4.49135	-.83811	7.1	3.8	89527.	7.0	6.8	3.4	25.0	126.0	70.0	1240000.	40.
49567	3.91102	4.31527	-.40425	7.1	5.5	89604.	7.0	6.8	3.4	25.0	126.0	70.0	1240000.	60.
49567	3.61010	3.64625	-.03615	8.4	1.9	89451.	7.0	6.8	3.4	25.0	126.0	70.0	1240000.	280.
49567	4.07723	3.88930	.18793	8.4	3.8	89527.	7.0	6.8	3.4	25.0	126.0	70.0	1240000.	160.
49567	4.36492	4.24832	.11660	8.4	5.6	89604.	7.0	6.8	3.4	25.0	126.0	70.0	1240000.	70.
49567	5.12931	3.88930	1.24001	14.2	1.9	89451.	7.0	6.8	3.4	25.0	126.0	70.0	1240000.	160.
49567	5.79302	4.09342	1.69960	14.2	3.8	89527.	7.0	6.8	3.4	25.0	126.0	70.0	1240000.	100.
49567	6.20178	4.13919	2.06260	14.2	5.6	89604.	7.0	6.8	3.4	25.0	126.0	70.0	1240000.	90.
49569	3.12519	3.47712	-.35194	6.7	1.9	89451.	7.0	7.0	2.9	25.0	120.0	60.0	1380000.	460.
49569	3.52956	3.77815	-.24859	6.7	3.8	89527.	7.0	7.0	2.9	25.0	120.0	60.0	1380000.	230.
49569	3.77861	2.98759	.79102	6.7	5.6	89604.	7.0	7.0	2.9	25.0	120.0	60.0	1380000.	1420.
49569	3.31416	3.59581	-.28165	7.3	1.9	89451.	7.0	7.0	2.9	25.0	120.0	60.0	1380000.	350.
49569	3.74300	3.85460	-.11160	7.3	3.8	89527.	7.0	7.0	2.9	25.0	120.0	60.0	1380000.	180.
49569	4.00711	4.13988	-.13277	7.3	5.6	89604.	7.0	7.0	2.9	25.0	120.0	60.0	1380000.	100.
49569	4.97577	4.23679	.73898	13.5	1.9	89451.	7.0	7.0	2.9	25.0	120.0	60.0	1380000.	80.
49569	5.61952	4.83875	.78077	13.5	3.8	89527.	7.0	7.0	2.9	25.0	120.0	60.0	1380000.	20.
49569	6.01614	4.66275	1.35339	13.5	5.6	89604.	7.0	7.0	2.9	25.0	120.0	60.0	1380000.	30.
49571	2.82650	3.54040	-.71390	6.5	1.9	89451.	7.0	6.9	4.0	30.0	126.0	66.0	1180000.	340.
49571	3.19224	3.62472	-.43248	6.5	3.8	89527.	7.0	6.9	4.0	30.0	126.0	66.0	1180000.	280.
49571	3.41749	3.92575	-.50826	6.5	5.6	89604.	7.0	6.9	4.0	30.0	126.0	66.0	1180000.	140.
49571	2.78332	3.41867	-.63535	6.4	1.9	89451.	7.0	6.9	4.0	30.0	126.0	66.0	1180000.	450.
49571	3.14348	4.16879	-1.02531	6.4	3.8	89527.	7.0	6.9	4.0	30.0	126.0	66.0	1180000.	80.
49571	3.36526	4.37291	-1.00765	6.4	5.6	89604.	7.0	6.9	4.0	30.0	126.0	66.0	1180000.	50.
49571	4.40535	4.59470	-.18935	12.8	1.9	89451.	7.0	6.9	4.0	30.0	126.0	66.0	1180000.	30.
49571	4.97539	4.46982	.50557	12.8	3.8	89527.	7.0	6.9	4.0	30.0	126.0	66.0	1180000.	40.
49571	5.32646	5.07188	.25458	12.8	5.6	89604.	7.0	6.9	4.0	30.0	126.0	66.0	1180000.	10.
50256	2.92658	3.56543	-.63885	7.1	1.9	89451.	7.0	6.6	3.0	33.0	88.0	46.0	625000.	170.
50256	3.30527	3.30452	.00075	7.1	3.8	89527.	7.0	6.6	3.0	33.0	88.0	46.0	625000.	310.
50256	3.53850	3.79588	-.25738	7.1	5.6	89604.	7.0	6.6	3.0	33.0	88.0	46.0	625000.	100.
50256	2.72392	3.89279	-1.16887	6.4	1.9	89451.	7.0	6.6	3.0	33.0	88.0	46.0	625000.	80.
50256	3.07638	3.61979	-.54341	6.4	3.8	89527.	7.0	6.6	3.0	33.0	88.0	46.0	625000.	150.
50256	3.29345	4.09691	-.80345	6.4	5.6	89604.	7.0	6.	3.0	33.0	88.0	46.0	625000.	50.
50256	4.31133	4.19382	.11751	12.8	1.9	89451.	7.0	6.6	3.0	33.0	88.0	46.0	625000.	40.
50256	4.86920	4.79588	.07332	12.8	3.8	89527.	7.0	6.6	3.0	33.0	88.0	46.0	625000.	10.
50257	3.03262	3.25123	-.21861	7.5	1.9	89451.	7.0	6.7	2.8	33.0	88.0	42.0	535000.	300.
50257	3.42503	3.95020	-.52517	7.5	3.8	89527.	7.0	6.7	2.8	33.0	88.0	42.0	535000.	60.
50257	3.66670	3.55220	.11450	7.5	5.6	89604.	7.0	6.7	2.8	33.0	88.0	42.0	535000.	150.
50257	2.72935	3.31338	-.58405	6.4	1.9	89451.	7.0	6.7	2.8	33.0	88.0	42.0	535000.	260.

SAMP NO.	PREDICTED LOG KILL	OBSERVED LOG KILL	RESIDUAL	DOSE (MG/L)	D.T. (MIN)	GT	TEMP (C)	PH	TKN (MG/L)	BOD (MG/L)	TSS (MG/L)	VSS (MG/L)	INFLUENT F. COLI	EFFLUENT F. COLI
50257	3.08249	3.52423	-.44174	6.4	3.8	89527.	7.0	6.7	2.8	33.0	88.0	42.0	535000.	160.
50257	3.30000	4.25123	-.95123	6.4	5.6	89604.	7.0	6.7	2.8	33.0	88.0	42.0	535000.	30.
50257	4.31989	4.72835	-.40846	12.8	1.9	89451.	7.0	6.7	2.8	33.0	88.0	42.0	535000.	10.
50257	4.87888	4.02939	.84949	12.8	3.8	89527.	7.0	6.7	2.8	33.0	88.0	42.0	535000.	50.
50257	5.22313	4.12629	1.09684	12.8	5.6	89604.	7.0	6.7	2.8	33.0	88.0	42.0	535000.	40.
50259	2.68764	3.34242	-.65478	7.4	1.9	89451.	7.0	6.7	3.4	43.0	78.0	40.0	330000.	150.
50259	3.03541	3.81954	-.78413	7.4	3.8	89527.	7.0	6.7	3.4	43.0	78.0	40.0	330000.	50.
50259	3.24958	4.21748	-.96790	7.4	5.6	89604.	7.0	6.7	3.4	43.0	78.0	40.0	330000.	20.
50259	2.44523	3.31439	-.86915	6.4	1.9	89451.	7.0	6.7	3.4	43.0	78.0	40.0	330000.	160.
50259	2.76164	3.43933	-.67769	6.4	3.8	89527.	7.0	6.7	3.4	43.0	78.0	40.0	330000.	120.
50259	2.95650	3.56427	-.60777	6.4	5.6	89604.	7.0	6.7	3.4	43.0	78.0	40.0	330000.	90.
50259	3.86623	3.51851	.34772	12.8	1.9	89451.	7.0	6.7	3.4	43.0	78.0	40.0	330000.	100.
50259	4.36650	2.54538	1.82112	12.8	3.8	89527.	7.0	6.7	3.4	43.0	78.0	40.0	330000.	940.
50259	4.67460	4.51851	.15609	12.8	5.6	89604.	7.0	6.7	3.4	43.0	78.0	40.0	330000.	10.
50374	2.77600	3.55520	-.77921	6.7	1.9	89451.	7.0	6.7	3.4	34.0	112.0	42.0	790000.	220.
50374	3.13520	3.72154	-.58634	6.7	3.8	89527.	7.0	6.7	3.4	34.0	112.0	42.0	790000.	150.
50374	3.35642	3.48265	-.12623	6.7	5.6	89604.	7.0	6.7	3.4	34.0	112.0	42.0	790000.	260.
50374	2.74025	3.32942	-.58917	6.6	1.9	89451.	7.0	6.7	3.4	34.0	112.0	42.0	790000.	370.
50374	3.09483	3.66718	-.57235	6.6	3.8	89527.	7.0	6.7	3.4	34.0	112.0	42.0	790000.	170.
50374	3.31320	4.24557	-.93237	6.6	5.6	89604.	7.0	6.7	3.4	34.0	112.0	42.0	790000.	40.
50374	4.24919	3.72154	.52765	12.8	1.9	89451.	7.0	6.7	3.4	34.0	112.0	42.0	790000.	150.
50374	4.79925	3.94338	.85587	12.8	3.8	89527.	7.0	6.7	3.4	34.0	112.0	42.0	790000.	90.
50374	5.13790	4.59660	.54130	12.8	5.6	89604.	7.0	6.7	3.4	34.0	112.0	42.0	790000.	20.
50376	2.80273	3.31079	-.50806	6.4	1.9	89451.	7.0	6.7	3.3	30.0	114.0	44.0	450000.	220.
50376	3.16539	3.75012	-.58473	6.4	3.8	89527.	7.0	6.7	3.3	30.0	114.0	44.0	450000.	80.
50376	3.38874	3.61182	-.22308	6.4	5.6	89604.	7.0	6.7	3.3	30.0	114.0	44.0	450000.	110.
50376	2.88075	3.44909	-.56834	6.6	1.9	89451.	7.0	6.7	3.3	30.0	114.0	44.0	450000.	160.
50376	3.25351	3.22185	.03166	6.6	3.8	89527.	7.0	6.7	3.3	30.0	114.0	44.0	450000.	270.
50376	3.98308	4.35218	-.36910	6.6	5.6	89604.	7.0	6.7	3.3	30.0	114.0	44.0	450000.	20.
50376	4.43607	4.17609	.25998	12.8	1.9	89451.	7.0	6.7	3.3	30.0	114.0	44.0	450000.	30.
50376	5.01008	4.05115	.95893	12.8	3.8	89527.	7.0	6.7	3.3	30.0	114.0	44.0	450000.	40.
50376	5.36359	4.17609	1.18750	12.8	5.6	89604.	7.0	6.7	3.3	30.0	114.0	44.0	450000.	30.
50378	2.75972	3.03357	-.27384	6.4	1.9	89451.	7.0	6.7	3.8	31.0	114.0	44.0	605000.	560.
50378	3.11692	3.55131	-.43439	6.4	3.8	89527.	7.0	6.7	3.8	31.0	114.0	44.0	605000.	170.
50378	3.33975	3.63563	-.29588	6.4	5.6	89604.	7.0	6.7	3.8	31.0	114.0	44.0	605000.	140.
50378	2.83655	3.02588	-.18933	6.6	1.9	89451.	7.0	6.7	3.8	31.0	114.0	44.0	605000.	570.
50378	3.20359	3.35039	-.14680	6.6	3.8	89527.	7.0	6.7	3.8	31.0	114.0	44.0	605000.	270.
50378	3.42964	3.87866	-.44903	6.6	5.6	89604.	7.0	6.7	3.8	31.0	114.0	44.0	605000.	80.
50378	4.36801	3.74036	.62764	12.8	1.9	89451.	7.0	6.7	3.8	31.0	114.0	44.0	605000.	110.
50378	4.93321	4.30463	.62858	12.8	3.8	89527.	7.0	6.7	3.8	31.0	114.0	44.0	605000.	30.
50378	5.28130	3.78175	1.49955	12.8	5.6	89604.	7.0	6.7	3.6	31.0	114.0	44.0	605000.	100.
50526	3.00068	2.19957	.80111	7.5	2.2	53893.	4.0	6.8	3.1	22.7	11.0	1.0	19000.	120.
50526	3.24017	2.57978	.66039	7.5	3.4	53992.	4.0	6.8	3.1	22.7	11.0	1.0	19000.	50.
50586	2.98789	2.31654	.67135	5.8	1.9	89451.	4.0	6.8	3.1	18.3	40.0	13.0	114000.	550.
50586	3.37451	2.73468	.63983	5.8	3.8	89527.	4.0	6.8	3.1	18.3	40.0	13.0	114000.	210.
50586	3.61262	3.75587	-.14325	5.8	5.6	89604.	4.0	6.8	3.1	18.3	40.0	13.0	114000.	20.
50597	2.64505	3.70757	-1.06252	5.0	1.9	89451.	4.0	6.7	3.1	20.2	10.4	2.4	51000.	10.
50070	1.16947	.69381	.47566	7.2	1.9	89386.	10.0	6.9	5.6	119.0	148.0	96.0	1255000.	254000.
50070	1.47979	2.45519	-.97539	7.2	3.8	134084.	10.0	6.9	5.6	119.0	148.0	96.0	1255000.	4400.
50070	1.71714	4.25354	-2.53640	7.2	5.6	178765.	10.0	6.9	5.6	119.0	148.0	96.0	1255000.	70.
50070	.87857	.33521	.54336	4.7	1.9	89451.	10.0	6.9	5.6	119.0	148.0	96.0	1255000.	580000.

SAMP NO.	PREDICTED LOG KILL	OBSERVED LOG KILL	RESIDUAL	DOSE (MG/L)	D.T. (MIN)	GT	TEMP (C)	PH	TKN (MG/L)	BOD (MG/L)	TSS (MG/L)	VSS (MG/L)	INFLUENT F. COLI	EFFLUENT F. COLI
50070	.99225	.51886	.47339	4.7	3.8	69527.	10.0	6.9	5.6	119.0	148.0	96.0	1255000.	380000.
50070	1.06227	.68367	.37860	4.7	5.6	89604.	10.0	6.9	5.6	119.0	148.0	96.0	1255000.	260000.
50070	1.05530	1.65148	-.59618	6.2	1.9	89386.	10.0	6.9	5.6	119.0	148.0	96.0	1255000.	28000.
50070	1.19161	1.95251	-.76090	6.2	3.8	89397.	10.0	6.9	5.6	119.0	148.0	96.0	1255000.	14000.
50070	1.27543	2.87853	-1.60310	6.2	5.6	69409.	10.0	6.9	5.6	119.0	148.0	96.0	1255000.	1660.
50072	1.74515	.90580	.83935	7.2	1.9	89386.	10.0	6.6	6.4	78.0	129.0	77.0	805000.	100000.
50072	2.62114	4.42867	-1.80753	7.2	5.6	178783.	10.0	6.6	6.4	78.0	129.0	77.0	805000.	30.
50072	.93349	1.49082	-.55733	2.7	1.9	69451.	10.0	6.6	6.4	78.0	129.0	77.0	805000.	26000.
50072	1.05428	.21560	.83868	2.7	3.8	69527.	10.0	6.6	6.4	78.0	129.0	77.0	805000.	490000.
50072	1.12867	.42867	.70000	2.7	5.6	89604.	10.0	6.6	6.4	78.0	129.0	77.0	805000.	300000.
50072	1.61087	2.54786	-.93699	6.2	1.9	69386.	10.0	6.6	6.4	78.0	129.0	77.0	805000.	2280.
50072	1.81894	2.32601	-.50707	6.2	3.8	89397.	10.0	6.6	6.4	78.0	129.0	77.0	805000.	3800.
50074	2.44031	4.04139	-1.60108	7.2	3.8	134084.	10.0	7.2	6.0	71.0	94.0	60.0	440000.	40.
50074	2.53171	4.04242	-1.51071	7.2	5.6	178783.	10.0	7.2	6.0	71.0	94.0	60.0	440000.	20.
50074	.92824	.25251	.67572	2.4	1.9	69451.	10.0	7.2	6.0	71.0	94.0	60.0	440000.	246000.
50074	1.04835	.00998	1.03837	2.4	3.8	89527.	10.0	7.2	6.0	71.0	94.0	60.0	440000.	430000.
50074	1.74028	1.82390	-.08363	6.2	1.9	89386.	10.0	7.2	6.0	71.0	94.0	60.0	440000.	6600.
50074	1.96506	2.06367	-.09860	6.2	3.8	89397.	10.0	7.2	6.0	71.0	94.0	60.0	440000.	3800.
50076	1.88852	4.02119	-2.13267	7.2	1.9	89386.	10.0	7.3	7.1	72.0	97.0	54.0	420000.	40.
50076	2.77336	4.32222	-1.54886	7.2	5.6	178783.	10.0	7.3	7.1	72.0	97.0	54.0	420000.	20.
50076	1.00695	.29691	.70994	2.8	1.9	89451.	10.0	7.3	7.1	72.0	97.0	54.0	420000.	212000.
50076	1.13713	.73116	.40598	2.8	3.8	69527.	10.0	7.3	7.1	72.0	97.0	54.0	420000.	78000.
50076	1.21737	.14613	1.07124	2.8	5.6	89604.	10.0	7.3	7.1	72.0	97.0	54.0	420000.	300000.
50076	1.70482	1.84510	-.14028	6.2	1.9	69386.	10.0	7.3	7.1	72.0	97.0	54.0	420000.	6000.
50076	1.92457	2.11810	-.19352	6.2	3.8	89397.	10.0	7.3	7.1	72.0	97.0	54.0	420000.	3200.
50076	2.05995	3.22531	-1.16535	6.2	5.6	69409.	10.0	7.3	7.1	72.0	97.0	54.0	420000.	250.
50078	1.66640	4.13434	-2.46793	7.2	1.9	69386.	10.0	7.2	5.9	85.0	103.0	51.0	545000.	40.
50078	2.44679	4.13434	-1.68755	7.2	5.6	178783.	10.0	7.2	5.9	85.0	103.0	51.0	545000.	40.
50078	.57456	1.09284	-.51828	1.5	1.9	69451.	10.0	7.2	5.9	85.0	103.0	51.0	545000.	44000.
50078	.65467	1.20492	-.55025	1.5	3.8	69527.	10.0	7.2	5.9	85.0	103.0	51.0	545000.	34000.
50078	.70086	.43537	.26549	1.5	5.6	89604.	10.0	7.2	5.9	85.0	103.0	51.0	545000.	200000.
50078	1.50372	1.98821	-.48449	6.2	1.9	69355.	10.0	7.2	5.9	85.0	103.0	51.0	545000.	5600.
50078	1.69795	2.54887	-.85093	6.2	3.8	89397.	10.0	7.2	5.9	85.0	103.0	51.0	545000.	1540.
50078	1.81738	4.25927	-2.44189	6.2	5.6	89409.	10.0	7.2	5.9	85.0	103.0	51.0	545000.	30.
50080	2.43355	4.33244	-1.89878	6.8	3.8	134054.	10.0	7.1	4.9	68.0	97.0	60.0	215000.	10.
50080	2.42399	4.03141	-1.20742	6.8	5.6	178785.	10.0	7.1	4.9	68.0	97.0	60.0	215000.	20.
50080	.68106	1.48734	-.80628	1.4	1.9	69451.	10.0	7.1	4.9	68.0	97.0	60.0	215000.	7000.
50080	.76919	1.10199	-.33280	1.4	3.8	69527.	10.0	7.1	4.9	68.0	97.0	60.0	215000.	17000.
50080	.82347	1.15635	-.33288	1.4	5.6	89604.	10.0	7.1	4.9	68.0	97.0	60.0	215000.	15000.
50080	1.81622	2.65120	-.83497	6.2	1.9	64386.	10.0	7.1	4.9	68.0	97.0	60.0	215000.	480.
50080	2.05092	3.18631	-1.13549	6.2	3.8	89397.	10.0	7.1	4.9	68.0	97.0	60.0	215000.	140.
50080	2.19508	4.03141	-1.83633	6.2	5.6	69409.	10.0	7.1	4.9	68.0	97.0	60.0	215000.	20.
52105	1.92610	2.14111	-.21501	3.6	1.3	41114.	16.0	7.0	3.5	3.0	6.0	1.4	155000.	1120.
52105	2.17499	2.27652	-.10152	3.6	2.6	41126.	16.0	7.0	3.5	3.0	6.0	1.4	155000.	820.
52105	2.33532	2.86811	-.53279	3.6	3.9	41138.	16.0	7.0	3.5	3.0	6.0	1.4	155000.	210.
52131	2.05111	2.07058	-.01947	4.0	1.3	41114.	16.0	7.0	3.7	3.4	7.5	1.4	80000.	680.
52131	2.31616	2.14721	.16895	4.0	2.6	41126.	16.0	7.0	3.7	3.4	7.5	1.4	80000.	570.
52131	2.48659	2.52265	-.03598	4.0	3.9	41138.	16.0	7.0	3.7	3.4	7.5	1.4	80000.	240.
52107	2.72119	1.97517	.74601	6.3	1.3	49450.	16.0	7.0	4.7	6.0	19.0	9.0	340000.	3600.
52107	3.07278	2.21972	.85306	6.3	2.6	49462.	16.0	7.0	4.7	6.0	19.0	9.0	340000.	2050.
52107	3.29424	2.71856	.57568	6.3	3.9	49474.	16.0	7.0	4.7	6.0	19.0	9.0	340000.	650.

SAMP NO.	PREDICTED LOG KILL	OBSERVED LOG KILL	RESIDUAL	DOSE (MG/L)	D.T. (MIN)	GT	TEMP (B)	PH	TKN (MG/L)	BOD (MG/L)	TSS (MG/L)	VSS (MG/L)	INFLUENT F. COLI	EFFLUENT F. COLI
52109	2.74693	2.19629	.55064	6.2	1.3	49450.	16.0	7.0	6.7	4.4	7.0	4.0	220000.	1400.
52109	3.10155	1.83727	1.26458	6.2	2.6	49462.	16.0	7.0	6.7	4.4	7.0	4.0	220000.	3200.
52109	3.33046	2.98069	.34977	6.2	3.9	49474.	16.0	7.0	6.7	4.4	7.0	4.0	220000.	230.
52111	4.39738	6.04139	-1.64401	11.9	1.3	49450.	16.0	7.0	3.5	4.0	7.5	3.5	110000.	0.
52111	4.96554	6.04139	-1.07584	11.9	2.6	49462.	16.0	7.0	3.5	4.0	7.5	3.5	110000.	0.
52111	5.33150	6.04139	-.70989	11.9	3.9	49474.	16.0	7.0	3.5	4.0	7.5	3.5	110000.	0.
52113	3.63459	6.25527	-2.62068	8.4	1.2	59776.	16.0	7.0	4.7	3.2	39.0	7.0	160000.	0.
52113	4.10421	6.25527	-2.15106	8.4	2.4	59791.	16.0	7.0	4.7	3.2	39.0	7.0	160000.	0.
52113	4.42789	6.25527	-1.82738	8.4	3.7	59805.	16.0	7.0	4.7	3.2	39.0	7.0	160000.	0.
52115	3.62353	4.00432	-.38079	8.4	1.2	59776.	16.0	7.0	6.7	1.6	6.3	1.0	101000.	10.
52115	4.09172	6.00432	-1.91260	8.4	2.4	59791.	16.0	7.0	6.7	1.6	6.3	1.0	101000.	0.
52115	4.41641	6.00432	-1.58791	8.4	3.7	59805.	16.0	7.0	6.7	1.6	6.3	1.0	101000.	0.
52117	3.81435	4.11394	-.29959	8.6	1.2	59776.	16.0	7.0	3.5	.7	3.0	.9	130000.	10.
52117	4.30719	6.11394	-1.80675	8.6	2.4	59791.	16.0	7.0	3.5	.7	3.0	.9	130000.	0.
52117	4.64688	6.11394	-1.46706	8.6	3.7	59805.	16.0	7.0	3.5	.7	3.0	.9	130000.	0.
52133	3.69262	3.84510	-.15248	8.6	1.2	59776.	16.0	7.0	3.7	3.6	1.3	.2	70000.	10.
52133	4.16973	5.84509	-1.67536	8.6	2.4	59791.	16.0	7.0	3.7	3.6	1.3	.2	70000.	0.
52133	4.49857	5.84509	-1.34652	8.6	3.7	59805.	16.0	7.0	3.7	3.6	1.3	.2	70000.	0.
52396	4.17520	4.03141	.14379	8.4	1.9	69386.	13.0	7.2	2.4	10.6	18.0	10.0	215000.	20.
52396	4.71450	4.03141	.68309	8.4	3.8	89397.	13.0	7.2	2.4	10.6	18.0	10.0	215000.	20.
52396	5.04613	4.33244	.71369	8.4	5.6	89409.	13.0	7.2	2.4	10.6	18.0	10.0	215000.	10.
52400	4.19543	4.32222	-.12679	8.4	1.9	69386.	13.0	7.1	3.5	9.1	25.0	15.0	210000.	10.
52400	4.73734	6.32222	-1.58488	8.4	3.8	69397.	13.0	7.1	3.5	9.1	25.0	15.0	210000.	0.
52400	5.07058	6.32222	-1.25164	8.4	5.6	69409.	13.0	7.1	3.5	9.1	25.0	15.0	210000.	0.
52404	3.52446	2.70602	.81844	6.2	1.9	69386.	13.0	6.8	3.3	6.4	24.0	19.0	970000.	1900.
52404	3.98196	3.57180	.41016	6.2	3.8	89397.	13.0	6.8	3.3	6.4	24.0	19.0	970000.	260.
52404	4.20205	4.62574	-.42369	6.2	5.6	89409.	13.0	6.8	3.3	6.4	24.0	19.0	970000.	20.
52408	3.45357	2.33288	1.12069	6.2	1.9	69386.	13.0	7.1	3.5	6.2	21.0	13.0	495000.	2300.
52408	3.89965	2.43933	1.46032	6.2	3.8	89397.	13.0	7.1	3.5	6.2	21.0	13.0	495000.	1800.
52408	4.17397	3.99563	.17833	6.2	5.6	89409.	13.0	7.1	3.5	6.2	21.0	13.0	495000.	50.
52442	2.05552	2.20926	-.15374	4.0	1.9	69386.	14.0	7.1	24.7	10.3	20.0	12.0	680000.	4200.
52442	2.32192	2.38535	-.06343	4.0	3.8	89397.	14.0	7.1	24.7	10.3	20.0	12.0	680000.	2800.
52442	2.48428	4.05436	-1.57007	4.0	5.6	69409.	14.0	7.1	24.7	10.3	20.0	12.0	680000.	60.
52446	2.84702	2.32736	.51966	4.0	3.8	69397.	14.0	7.1	3.8	10.6	18.0	16.0	425000.	2000.
52446	3.04728	3.39794	-.35066	4.0	5.6	69409.	14.0	7.1	3.8	10.6	18.0	16.0	425000.	170.
52684	1.71580	1.87335	-.15755	4.2	1.9	69386.	16.0	7.0	2.6	51.0	82.0	30.0	254000.	3400.
52684	2.17109	1.55974	.61136	4.2	3.8	134084.	16.0	7.0	2.6	51.0	82.0	30.0	254000.	7000.
52684	2.51931	1.55974	.95958	4.2	5.6	178783.	16.0	7.0	2.6	51.0	82.0	30.0	254000.	7000.
52684	1.60952	.40283	1.20669	4.0	1.9	69451.	16.0	7.0	2.6	51.0	82.0	30.0	254000.	87500.
52684	1.90588	.85663	1.04925	4.0	3.8	89527.	16.0	7.0	2.6	51.0	82.0	30.0	254000.	37000.
52684	2.01895	1.50174	.51721	4.0	5.6	69604.	16.0	7.0	2.6	51.0	82.0	30.0	254000.	8000.
52684	1.66947	.73274	.93674	4.0	1.9	69386.	16.0	7.0	2.6	51.0	82.0	30.0	254000.	47000.
52684	1.88511	1.10380	.78131	4.0	3.8	69397.	16.0	7.0	2.6	51.0	82.0	30.0	254000.	20000.
52684	2.01772	1.32565	.69207	4.0	5.6	69409.	16.0	7.0	2.6	51.0	82.0	30.0	254000.	12000.
52694	2.23596	1.60974	.62622	4.9	1.9	69386.	16.0	7.2	3.0	35.0	80.0	32.0	285000.	7000.
52694	2.82920	1.74305	1.08615	4.9	3.8	134084.	16.0	7.2	3.0	35.0	80.0	32.0	285000.	5150.
52694	3.28307	2.47712	.80595	4.9	5.6	178783.	16.0	7.2	3.0	35.0	80.0	32.0	285000.	950.
52694	2.20296	1.37560	.82736	4.6	1.9	69451.	16.0	7.2	3.0	35.0	80.0	32.0	285000.	12000.
52694	2.48802	1.25072	1.23730	4.6	3.8	69527.	16.0	7.2	3.0	35.0	80.0	32.0	285000.	16000.
52694	2.66557	2.50545	.16012	4.8	5.6	69604.	16.0	7.2	3.0	35.0	80.0	32.0	285000.	890.
52694	2.03119	.85278	1.17841	4.2	1.9	69386.	16.0	7.2	3.0	35.0	80.0	32.0	285000.	40000.

SAMP NO.	PREDICTED LOG KILL	OBSERVED LOG KILL	RESIDUAL	DOSE (MG/L)	D.T. (MIN)	GT	TEMP (C)	PH	TKN (MG/L)	BOD (MG/L)	TSS (MG/L)	VSS (MG/L)	INFLUENT F. COLI	EFFLUENT F. COLI
52694	2.29355	1.25072	1.04283	4.2	3.8	89397.	16.0	7.2	3.0	35.0	80.0	32.0	285000.	16000.
52694	2.45439	1.87506	.57933	4.2	5.6	89409.	16.0	7.2	3.0	35.0	80.0	32.0	285000.	3800.
52704	2.71358	2.24917	.46441	6.5	1.9	89386.	16.0	7.0	2.9	35.0	152.0	95.0	205000.	1155.
52704	3.43363	2.54833	.88531	6.5	3.8	134084.	16.0	7.0	2.9	35.0	152.0	95.0	205000.	580.
52704	3.98436	2.93190	1.05281	6.5	5.6	178783.	16.0	7.0	2.9	35.0	152.0	95.0	205000.	240.
52704	2.65052	2.19781	.45271	6.3	1.9	89451.	16.0	7.0	2.9	35.0	152.0	95.0	205000.	1300.
52704	2.99349	2.37726	.61623	6.3	3.8	89527.	16.0	7.0	2.9	35.0	152.0	95.0	205000.	860.
52704	3.20471	3.23257	-.02787	6.3	5.6	89604.	16.0	7.0	2.9	35.0	152.0	95.0	205000.	120.
52704	2.71358	1.96933	.74425	6.5	1.9	89386.	16.0	7.0	2.9	35.0	152.0	95.0	205000.	2200.
52704	3.06408	2.23257	.83151	6.5	3.8	89397.	16.0	7.0	2.9	35.0	152.0	95.0	205000.	1200.
52704	3.27962	3.03300	.24661	6.5	5.6	89409.	16.0	7.0	2.9	35.0	152.0	95.0	205000.	190.
52714	2.59470	2.03892	.55578	6.2	1.9	89386.	16.0	7.0	2.9	36.0	80.0	30.0	175000.	1600.
52714	3.28320	2.25181	1.03139	6.2	3.8	134084.	16.0	7.0	2.9	36.0	80.0	30.0	175000.	980.
52714	3.80950	2.94171	.86779	6.2	5.6	178783.	16.0	7.0	2.9	36.0	80.0	30.0	175000.	200.
52714	2.68578	1.61979	1.06600	6.5	1.9	89451.	16.0	7.0	2.9	36.0	80.0	30.0	175000.	4200.
52714	3.03351	2.55004	.48347	6.5	3.8	89527.	16.0	7.0	2.9	36.0	80.0	30.0	175000.	490.
52714	3.24735	2.66325	.58409	6.5	5.6	89604.	16.0	7.0	2.9	36.0	80.0	30.0	175000.	380.
52714	2.66899	1.88141	.78758	6.5	1.9	89386.	16.0	7.0	2.9	36.0	80.0	30.0	175000.	2300.
52714	3.01362	2.18996	.82366	6.5	3.8	89397.	16.0	7.0	2.9	36.0	80.0	30.0	175000.	1130.
52714	3.22551	3.12909	.09651	6.5	5.6	89409.	16.0	7.0	2.9	36.0	80.0	30.0	175000.	130.
52724	3.23469	3.36172	-.12703	8.3	1.9	89386.	16.0	7.0	5.5	31.0	82.0	32.0	345000.	150.
52724	4.09302	4.23679	-.14376	8.3	3.8	134084.	16.0	7.0	5.5	31.0	82.0	32.0	345000.	20.
52724	3.25335	2.52288	.73048	8.4	1.9	89451.	16.0	7.0	5.5	31.0	82.0	32.0	345000.	1035.
52724	3.67432	3.75966	-.08534	8.4	3.8	89527.	16.0	7.0	5.5	31.0	82.0	32.0	345000.	80.
52724	3.93359	4.06069	-.12711	8.4	5.6	89604.	16.0	7.0	5.5	31.0	82.0	32.0	345000.	30.
52724	3.23469	2.59333	.64136	8.3	1.9	89386.	16.0	7.0	5.5	31.0	82.0	32.0	345000.	880.
52724	3.55250	3.59272	-.04022	8.3	3.8	89397.	16.0	7.0	5.5	31.0	82.0	32.0	345000.	70.
52734	3.31847	2.15112	1.16735	8.4	1.9	89386.	16.0	7.0	2.9	32.0	84.0	36.0	245000.	1730.
52734	4.19904	2.89780	1.30124	8.4	3.8	134084.	16.0	7.0	2.9	32.0	84.0	36.0	245000.	310.
52734	4.87253	3.30998	1.56254	8.4	5.6	178783.	16.0	7.0	2.9	32.0	84.0	36.0	245000.	120.
52734	3.25114	2.73595	.51519	8.2	1.9	89451.	16.0	7.0	2.9	32.0	84.0	36.0	245000.	450.
52734	3.67153	4.08814	-.41661	8.2	3.8	89527.	16.0	7.0	2.9	32.0	84.0	36.0	245000.	20.
52734	3.93591	4.38916	-.45325	8.2	5.6	89604.	16.0	7.0	2.9	32.0	84.0	36.0	245000.	10.
52734	3.23205	2.30638	.92567	8.1	1.9	89386.	16.0	7.0	2.9	32.0	84.0	36.0	245000.	1210.
52734	3.64952	3.06695	.58257	8.1	3.8	89397.	16.0	7.0	2.9	32.0	84.0	36.0	245000.	210.

ClO_2 DATA

SAMP NO.	PREDICTED LOG KILL	OBSERVED LOG KILL	RESIDUAL	DOSE (MG/L)	D.T. (MIN)	GT	TEMP (C)	PH	TKN (MG/L)	BOD (MG/L)	TSS (MG/L)	VSS (MG/L)	INFLUENT F. COLI	EFFLUENT F. COLI
51677	2.03878	1.45484	.58394	1.8	1.3	41189.	17.0	6.7	4.0	11.4	36.0	11.0	142500.	5000.
51677	2.07881	1.11242	.96640	1.8	2.6	41277.	17.0	6.7	4.0	11.4	36.0	11.0	142500.	11000.
51677	2.10268	1.11242	.99027	1.8	3.9	41364.	17.0	6.7	4.0	11.4	36.0	11.0	142500.	11000.
51683	1.64226	3.25527	-1.61301	1.5	1.3	41189.	17.0	6.7	2.5	16.0	17.0	6.0	18000.	10.
51683	1.69373	3.25527	-1.56154	1.5	3.9	41364.	17.0	6.7	2.5	16.0	17.0	6.0	18000.	10.
51689	1.75457	2.78837	-1.03380	1.3	1.3	41189.	17.0	6.7	2.0	6.6	13.0	6.0	43000.	70.
51689	1.78913	2.85532	-1.06619	1.3	2.6	41277.	17.0	6.7	2.0	6.6	13.0	6.0	43000.	60.
51692	1.79772	3.77452	-1.97680	1.3	1.3	41189.	17.0	6.7	1.8	6.2	6.0	4.7	59500.	10.
51692	1.83302	2.57040	-.73738	1.3	2.6	41277.	17.0	6.7	1.8	6.2	8.0	4.7	59500.	160.
51692	1.85407	2.92942	-1.07535	1.3	3.9	41364.	17.0	6.7	1.8	6.2	8.0	4.7	59500.	70.
51678	3.56161	2.89854	.66307	3.7	1.3	49522.	17.0	6.7	4.0	4.7	25.3	5.3	142500.	180.
51678	3.67309	3.67669	-.00360	3.7	3.9	49691.	17.0	6.7	4.0	4.7	25.3	5.3	142500.	30.
51684	3.07156	2.65321	.41835	3.0	1.3	49522.	17.0	6.7	2.5	5.7	5.2	2.0	18000.	40.
51684	3.13211	2.55630	.57581	3.0	2.6	49607.	17.0	6.7	2.5	5.7	5.2	2.0	18000.	50.
51684	3.16801	2.35218	.81583	3.0	3.9	49691.	17.0	6.7	2.5	5.7	5.2	2.0	18000.	80.
51690	2.92491	3.03643	-.11152	2.6	2.6	49607.	17.0	6.7	2.0	3.7	8.0	3.0	43500.	40.
51753	3.03020	2.59843	.43177	2.7	3.9	49691.	17.0	6.7	1.8	3.7	7.0	4.5	59500.	150.
51685	4.23296	2.47712	1.75584	4.5	1.2	59855.	17.0	6.7	2.5	1.8	10.0	2.5	18000.	60.
51685	4.36873	2.47712	1.89161	4.5	3.7	60042.	17.0	6.7	2.5	1.8	10.0	2.5	18000.	60.
51691	3.86919	3.63849	.23070	4.1	1.2	59855.	17.0	6.7	2.0	3.1	5.5	2.4	43500.	10.
51691	3.99330	2.73540	1.25790	4.1	3.7	60042.	17.0	6.7	2.0	3.1	5.5	2.4	43500.	80.
51754	3.85845	2.87143	.98702	4.0	3.7	60042.	17.0	6.7	1.8	4.9	5.5	3.1	59500.	80.
52299	2.34342	3.61055	-1.26713	2.1	1.9	89386.	14.0	7.0	4.4	11.2	22.0	16.0	775000.	190.
52299	2.38919	3.81012	-1.42093	2.1	3.8	89397.	14.0	7.0	4.4	11.2	22.0	16.0	775000.	120.
52299	2.41520	4.11115	-1.69595	2.1	5.6	89409.	14.0	7.0	4.4	11.2	22.0	16.0	775000.	60.
52303	2.47449	3.29275	-.81826	2.1	1.9	89386.	14.0	6.9	4.6	6.0	48.0	24.0	1040000.	530.
52303	2.52282	3.60206	-1.07924	2.1	3.8	89397.	14.0	6.9	4.6	6.0	48.0	24.0	1040000.	260.
52303	2.55026	3.69481	-1.14455	2.1	5.6	89409.	14.0	6.9	4.6	6.0	48.0	24.0	1040000.	210.
52384	5.04078	5.28780	-.24702	5.8	1.9	89386.	13.0	6.9	3.6	3.1	31.0	20.0	1940000.	10.
52384	5.13923	5.28780	-.14857	5.8	3.8	89397.	13.0	6.9	3.6	3.1	31.0	20.0	1940000.	10.
52388	5.22015	3.83885	1.38131	5.8	3.8	89397.	13.0	7.0	3.7	2.2	28.0	21.0	345000.	50.
52388	5.27697	4.23679	1.04019	5.8	5.6	89409.	13.0	7.0	3.7	2.2	28.0	21.0	345000.	20.
52468	2.88992	2.97772	-.08780	4.8	1.9	89386.	11.0	6.6	6.4	31.0	39.0	12.0	9500.	10.
52468	3.00696	2.97772	.02924	4.8	3.8	134084.	11.0	6.6	6.4	31.0	39.0	12.0	9500.	10.
52468	3.08291	2.97772	.10519	4.8	5.6	178783.	11.0	6.6	6.4	31.0	39.0	12.0	9500.	10.
52468	2.89002	2.97772	-.08770	4.8	1.9	89451.	11.0	6.6	6.4	31.0	39.0	12.0	9500.	10.
52468	2.94658	2.67669	.26989	4.8	3.8	89527.	11.0	6.6	6.4	31.0	39.0	12.0	9500.	20.
52468	2.97876	2.50060	.47816	4.8	5.6	89634.	11.0	6.6	6.4	31.0	39.0	12.0	9500.	30.
52468	2.94637	2.97772	-.03136	4.8	3.8	89397.	11.0	6.6	6.4	31.0	39.0	12.0	9500.	10.
52468	2.97844	2.97772	.00071	4.8	5.6	89409.	11.0	6.6	6.4	31.0	39.0	12.0	9500.	10.
52624	1.51819	.91576	.60243	1.9	1.9	89386.	16.0	7.0	2.6	34.0	100.0	35.0	156500.	19000.
52624	1.57938	.83279	.74659	1.9	3.8	134084.	16.0	7.0	2.5	34.0	100.0	35.0	156500.	23000.
52624	1.62010	.99039	.62971	1.9	5.6	178783.	16.0	7.0	2.6	34.0	100.0	35.0	156500.	16000.
52624	1.51824	.56104	.95720	1.9	1.9	89451.	16.0	7.0	2.6	34.0	100.0	35.0	156500.	43000.
52624	1.54796	.70315	.84481	1.9	3.8	89527.	16.0	7.0	2.6	34.0	100.0	35.0	156500.	31000.
52624	1.56486	.99039	.57447	1.9	5.6	89604.	16.0	7.0	2.6	34.0	100.0	35.0	156500.	16000.
52624	1.51819	1.15312	.36507	1.9	1.9	89386.	16.0	7.0	2.5	34.0	100.0	35.0	156500.	11000.
52624	1.54784	1.19451	.35333	1.9	3.8	89397.	16.0	7.0	2.6	34.0	100.0	35.0	156500.	10000.
52624	1.56464	1.34941	.21523	1.9	5.6	89409.	16.0	7.0	2.6	34.0	100.0	35.0	156500.	7000.
52634	1.56415	1.77207	-.20792	2.0	1.9	89386.	16.0	7.0	2.8	34.0	100.0	42.0	213000.	3600.
52634	1.62750	1.83702	-.20951	2.0	3.8	134084.	16.0	7.0	2.8	34.0	100.0	42.0	213000.	3100.

SAMP NO.	PREDICTED LOG KILL	OBSERVED LOG KILL	RESIDUAL	DOSE (MG/L)	D.T. (MIN)	GT	TEMP (C)	PH	TKN (MG/L)	BOD (MG/L)	TSS (MG/L)	VSS (MG/L)	INFLUENT F. COLI	EFFLUENT F. COLI
52634	1.66915	1.55023	.11892	2.0	5.6	178783.	16.0	7.0	2.8	34.0	100.0	42.0	213000.	6000.
52634	1.56052	1.04962	.51100	2.0	1.9	85451.	16.0	7.0	2.8	34.0	100.0	42.0	213000.	19000.
52634	1.59482	1.21443	.38039	2.0	3.8	89527.	16.0	7.0	2.8	34.0	100.0	42.0	213000.	13000.
52534	1.61224	1.43628	.17596	2.0	5.6	89604.	16.0	7.0	2.8	34.0	100.0	42.0	213000.	7800.
52634	1.56415	1.12426	.43990	2.0	1.9	89386.	16.0	7.0	2.8	34.0	100.0	42.0	213000.	16000.
52634	1.59470	1.28698	.30772	2.0	3.8	89397.	16.0	7.0	2.8	34.0	100.0	42.0	213000.	11000.
52634	1.61206	1.15229	.45978	2.0	5.6	89409.	16.0	7.0	2.8	34.0	100.0	42.0	213000.	15000.
52644	2.34804	3.91645	-1.56841	4.0	1.9	89386.	16.0	7.0	2.7	35.0	90.0	38.0	165000.	20.
52544	2.44313	4.21748	-1.77434	4.0	3.8	134084.	16.0	7.0	2.7	35.0	90.0	38.0	165000.	10.
52544	2.50565	3.74036	-1.23471	4.0	5.6	178783.	16.0	7.0	2.7	35.0	90.0	38.0	165000.	30.
52644	2.34812	2.68600	-.33788	4.0	1.9	89451.	16.0	7.0	2.7	35.0	90.0	38.0	165000.	340.
52544	2.39407	2.96221	-.56813	4.0	3.8	89527.	16.0	7.0	2.7	35.0	90.0	38.0	165000.	180.
52544	2.42022	3.01336	-.59314	4.0	5.6	89604.	16.0	7.0	2.7	35.0	90.0	38.0	165000.	160.
52544	2.34804	2.50991	-.16187	4.0	1.9	89386.	16.0	7.0	2.7	35.0	90.0	38.0	165000.	510.
52644	2.39390	2.53624	-.14234	4.0	3.8	89397.	16.0	7.0	2.7	35.0	90.0	38.0	165000.	480.
52644	2.41996	2.61542	-.19546	4.0	5.6	89409.	16.0	7.0	2.7	35.0	90.0	38.0	165000.	400.
52654	2.25410	3.27684	-1.02275	4.2	1.9	89386.	16.0	7.0	2.8	39.0	95.0	30.0	227000.	120.
52654	2.30539	3.41293	-1.10755	4.2	3.8	134084.	16.0	7.0	2.8	39.0	95.0	30.0	227000.	80.
52654	2.40541	3.87890	-1.47350	4.2	5.6	178783.	16.0	7.0	2.8	39.0	95.0	30.0	227000.	30.
52654	2.27796	2.77624	-.49828	4.2	1.9	89451.	16.0	7.0	2.8	39.0	95.0	30.0	227000.	380.
52654	2.32254	2.69327	-.37073	4.2	3.8	89527.	16.0	7.0	2.8	39.0	95.0	30.0	227000.	460.
52654	2.34791	2.86466	-.51676	4.2	5.6	89604.	16.0	7.0	2.8	39.0	95.0	30.0	227000.	310.
52654	2.25410	2.51093	-.25683	4.2	1.9	89386.	16.0	7.0	2.8	39.0	95.0	30.0	227000.	700.
52654	2.29812	2.86466	-.56654	4.2	3.8	89397.	16.0	7.0	2.8	39.0	95.0	30.0	227000.	310.
52554	2.32314	3.03380	-.71067	4.2	5.6	89409.	16.0	7.0	2.8	39.0	95.0	30.0	227000.	210.
52664	3.02496	2.83286	.19210	6.0	1.9	89386.	16.0	7.0	2.9	35.0	85.0	30.0	245000.	360.
52668	3.14748	3.15872	-.01124	6.0	3.8	134084.	16.0	7.0	2.9	35.0	85.0	30.0	245000.	170.
52564	3.22802	3.34777	-.11976	6.0	5.6	178783.	16.0	7.0	2.9	35.0	85.0	30.0	245000.	110.
52564	3.02507	2.99123	.03385	6.0	1.9	89451.	16.0	7.0	2.9	35.0	85.0	30.0	245000.	250.
52564	3.08427	3.04674	.03753	6.0	3.8	89527.	16.0	7.0	2.9	35.0	85.0	30.0	245000.	220.
52564	3.11795	3.48608	-.36812	6.0	5.6	89604.	16.0	7.0	2.9	35.0	85.0	30.0	245000.	80.
52664	3.02496	3.30998	-.28502	6.0	1.9	89386.	16.0	7.0	2.9	35.0	85.0	30.0	245000.	120.
52664	3.08675	3.24524	-.15849	6.0	3.8	89397.	16.0	7.0	2.9	35.0	85.0	30.0	245000.	140.
52564	3.11761	3.54407	-.42645	6.0	5.6	89409.	16.0	7.0	2.9	35.0	85.0	30.0	245000.	70.
52574	3.22012	3.21307	.00705	6.4	1.9	89386.	16.0	7.0	2.8	34.0	93.0	38.0	294000.	180.
52674	3.35054	3.38916	-.03863	6.4	3.8	134084.	16.0	7.0	2.8	34.0	93.0	38.0	294000.	120.
52674	3.43627	3.42695	.00932	6.4	5.6	178783.	16.0	7.0	2.8	34.0	93.0	38.0	294000.	110.
52574	3.22024	3.05337	.16686	6.4	1.9	89451.	16.0	7.0	2.8	34.0	93.0	38.0	294000.	260.
52574	3.28326	3.21307	.07018	6.4	3.8	89527.	16.0	7.0	2.8	34.0	93.0	38.0	294000.	180.
52574	3.31911	3.46835	-.14923	6.4	5.6	89604.	16.0	7.0	2.8	34.0	93.0	38.0	294000.	100.
52574	3.22012	2.87725	.34284	6.4	1.9	89386.	16.0	7.0	2.8	34.0	93.0	38.0	294000.	390.
52674	3.28302	3.21307	.06994	6.4	3.8	89397.	16.0	7.0	2.8	34.0	93.0	38.0	294000.	180.
52674	3.31875	3.69019	-.37144	6.4	5.6	89409.	16.0	7.0	2.8	34.0	93.0	38.0	294000.	60.